ENGINEERING REPORT
FIGURE EIGHT ISLAND INLET AND SHORELINE MANAGEMENT PROJECT

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**ENGINEERING REPORT**
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**Table of Contents**



List of Figures

Figure No.

List of Figures

Figure No.

List of Figures

Figure No.

List of Figures

Figure No.

List of Figures



List of Tables

List of Tables

Table No.



List of Sub-Appendices

Sub-Appendix

ENGINEERING REPORT
FIGURE EIGHT ISLAND INLET AND SHORELINE MANAGEMENT PROJECT

## 1.0 INTRODUCTION

Figure Eight Island is one of a number of barrier islands located along the North Carolina coast in New Hanover County. Figure Eight Island is bordered by Rich Inlet to the north and Mason Inlet to the south (Figure 1-1). The Figure "8" Beach Homeowners Association has an interest in developing a long-term Beach Protection and Management Plan that covers the 4.9 miles of oceanfront shoreline. Approximately 22,130 ft of the Figure Eight Island oceanfront shoreline is developed. Two low-lying spits extend from the developed section of the island toward the adjacent inlets. The northern spit extending towards Rich Inlet is currently ~ 2,100 ft long and the southern spit that extends toward Mason Inlet is ~ 1,500 feet. Both areas are characterized by severe shoreline change.

Rich Inlet is a relatively large inlet that separates Hutaff Island, an undeveloped barrier to the northeast, from Figure Eight Island extending to the southwest. The inlet drains an expansive marsh-filled lagoon where two large tidal creeks, Nixon and Green Channels, connect the inlet to the Atlantic Intracoastal Waterway (AIWW). Although it is relatively stable, Rich Inlet has the capability to promote considerable oceanfront shoreline changes through complex linkages to ebb channel movement and ebb-tidal delta shape changes. Currently, Figure Eight Island is confronted with serious management issues that concern inlet hazard zones and the severe recurring oceanfront erosion. Even though the inlet has been a fairly stable feature since the early 1990's, there have been substantial shoreline changes along both sides of the inlet and the adjacent oceanfront.

At least 11 known beach nourishment projects of varying size have been completed along various shoreline segments of Figure Eight Island since June of 1984 to mitigate erosion. Nourishment activities have increased since the mid to late 1990's due to changes within Mason and Rich Inlets systems and the increase in storm activity. These projects combined have placed an estimated total volume of approximately 4 million cubic yards of beach fill along the island. The island's shoreline maintenance projects have typically involved mitigation efforts along erosion hot spots along the northern and southern segments of the island.

## 2.0 PROBLEM IDENTIFICATION

The Homeowners Association and island residents have struggled with the continuing problems associated with Rich and Mason Inlets, including long-term chronic erosion that has been exacerbated by a series of hurricanes in the 1990's. The Association is continuing to explore inlet management and beach renourishment options to: (1) preserve the integrity of its infrastructure, (2) provide protection to the existing development, which thereby would maintain or increase property values, and (3) ensure the continued use of the oceanfront beach and its adjacent navigable waterways. Information contained in this report provides a framework for formulating a Long-Term Figure Eight Island Beach Management Strategy.

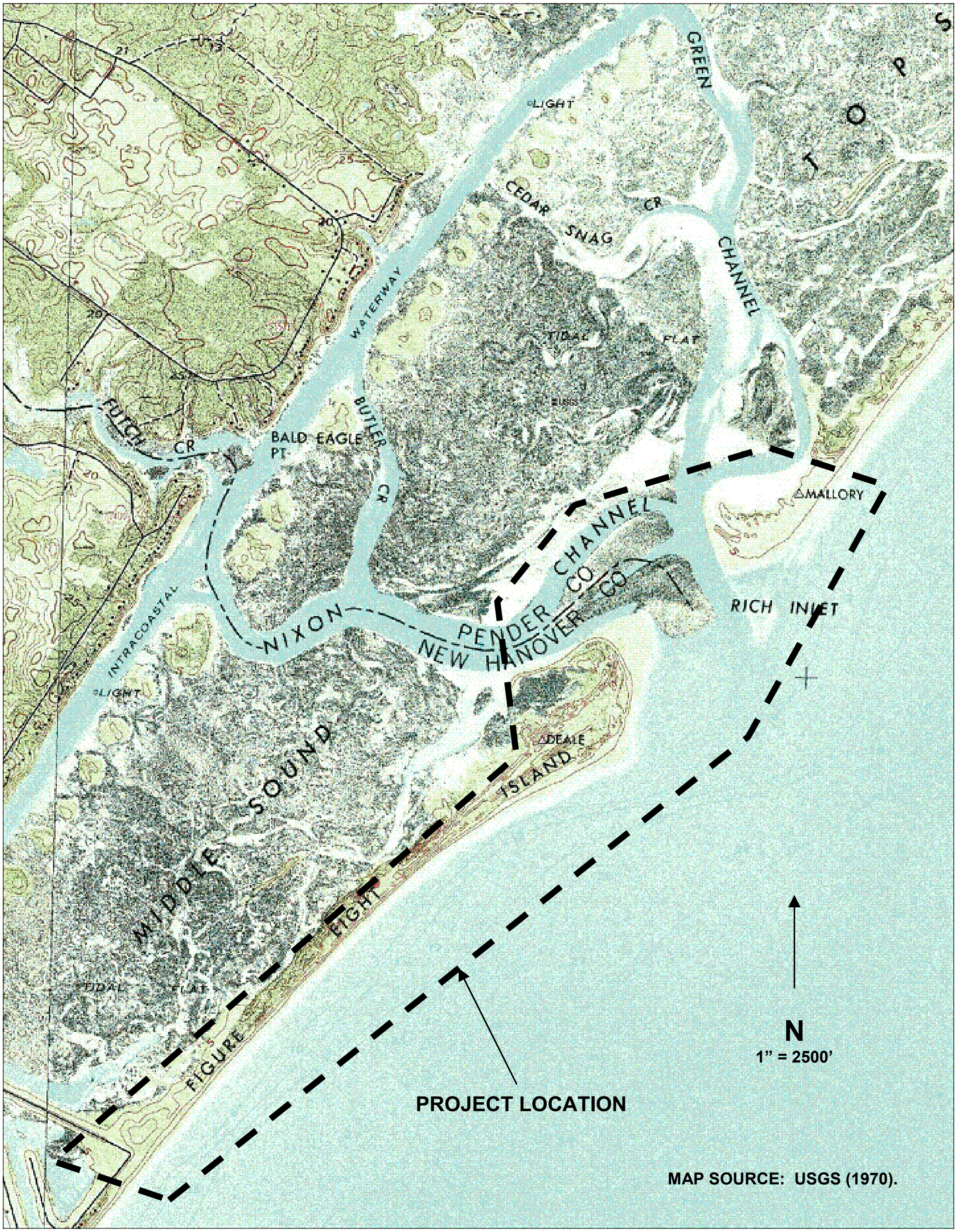



**FIGURE 1-1: Figure Eight Island Project Location.**

The State of North Carolina passed the Coastal Area Management Act (CAMA) in 1974 as a means of regulating ocean front development, which ultimately led to a ban on hard structures as a form of shoreline stabilization. In 2003, the North Carolina General Assembly enacted a law that prohibited the use of hard structures as a form of erosion mitigation. During the 2009 North Carolina Legislative Session, a bill was passed by the NC Senate (Senate Bill 832) that would allow the Coastal Resources Commission to permit the installation of a terminal groin, either by variance or rule making, providing an Environmental Impact Statement found the terminal groin to be the preferred sediment management device. Senate Bill 832 would also require the permittee to monitor the performance of the terminal groin and have it removed should it produce undesirable impacts. Senate Bill 832 did not make it out of the House; rather, the House passed House Bill 709 authorizing a study of terminal groins. The terminal groin study was completed in early 2010. Accordingly, this document presents two solutions to the erosion problem on the north end of Figure Eight Island:

1. Modification of the Rich Inlet entrance channel with beach fill.
2. Terminal groin with beach fill and maintenance dredging in Nixon Channel.

Even if the terminal groin bill passes, both solutions will be available to the Homeowners Association. If the terminal groin bill does not pass, only the first solution will be available.

## 3.0 COASTAL CONSISTENCY

The consistency of this project with the Coastal Barrier Resources Act and Coastal Barrier Improvement Act of 1990 will be discussed in the Environmental Impact Statement for the project.

## 4.0 PHYSICAL CHARACTERISTICS OF THE PROJECT AREA

### 4.1 General Description

Barrier islands, such as Figure Eight Island, are composed of unconsolidated fine to medium sized quartz and shell material that is in a constant state of flux due to wind, waves, currents and storms. The oceanfront beach and the backing dunes are deposits of sand that are constantly changing their shape, and hence position with time as they respond to coastal processes.

Figure Eight Island is located within the southern coastal unit that extends from Cape Lookout to Sunset Beach, NC. The continental shelf sediment between Cape Lookout and Cape Fear is locally known as Onslow Bay. The sediment cover in Onslow Bay is generally thin as indicated by a large frequency of rock outcrops.

### 4.2 Tides

Ocean tides on Figure Eight Island are semi-diurnal, with a spring-neap variation of 28 days. Oceanfront tides are based on the NOAA tide gage and benchmark on Johnny Mercer's Pier in Wrightsville Beach. This benchmark is the closest oceanfront tidal benchmark established by NOAA. Tidal datums at Wrightsville Beach appear in Table 4-1. The mean tidal range is approximately 4.1 feet.

**TABLE 4-1**

**NOAA (2003) OCEANFRONT TIDAL DATUMS**
**WRIGHTSVILLE BEACH, NC**

| TIDAL DATUM | ELEVATION (feet MLLW) | (feet NGVD) | (feet NAVD) |
|---|---|---|---|
| MEAN HIGHER HIGH WATER (MHHW) | 4.64 | 3.01 | 2.05 |
| MEAN HIGH WATER (MHW) | 4.29 | 2.66 | 1.70 |
| NORTH AMERICAN VERTICAL DATUM-1988 (NAVD) | 2.59 | 0.96 | 0.00 |
| MEAN TIDE LEVEL (MTL) | 2.22 | 0.59 | -0.37 |
| MEAN SEA LEVEL (MSL) | 2.22 | 0.59 | -0.37 |
| NATIONAL GEODETIC VERTICAL DATUM-1929 (NGVD) | 1.63 | 0.00 | -0.96 |
| MEAN LOW WATER (MLW) | 0.15 | -1.47 | -2.43 |
| MEAN LOWER LOW WATER (MLLW) | 0.00 | -1.63 | -2.59 |

Additional water level measurements were collected May 25-July, 2005 by Gahagan & Bryant Associates (GBA). These measurements covered 7 different locations within Rich Inlet and the Atlantic Intracoastal Waterway (AIWW). The locations of the 7 tide gages appear in Figure 4-1. Tidal datums based on the measurements appear in Table 4-2. The water levels measured by GBA were used to calibrate and verify the current, water level, and bathymetric change model for Rich Inlet. Tidal ranges inside the AIWW range from 3.2 to 3.6 feet. The tidal range in the throat of the inlet is approximately 3.7 feet. Tides in the AIWW lag the Wrightsville Beach tides by approximately 1 hour. Tides in the throat of Rich Inlet lag the Wrightsville Beach tides by approximately 30 minutes.

**TABLE 4-2**

**INTERIOR TIDAL DATUMS**
**RICH INLET, NC**

| GBA Tide Gage | NC-NAD83 Easting (feet) | NC-NAD83 Northing (feet) | MHHW (feet NAVD) | MHW (feet NAVD) | MTL (feet NAVD) | MLW (feet NAVD) | MLLW (feet NAVD) |
|---|---|---|---|---|---|---|---|
| Green Channel | 2388810 | 206816 | 1.9 | 1.3 | -0.3 | -2.0 | -2.3 |
| Nixon Channel | 2383594 | 200566 | 2.2 | 1.6 | -0.2 | -1.9 | -2.2 |
| Inlet Throat | 2388940 | 202433 | 2.2 | 1.7 | -0.2 | -2.0 | -2.3 |
| AIWW North | 2387756 | 211356 | 2.0 | 1.5 | -0.2 | -1.8 | -2.0 |
| AIWW South | 2378296 | 199045 | 2.3 | 1.7 | -0.1 | -1.9 | -2.1 |
| AIWW Middle | 2382804 | 208892 | 2.1 | 1.5 | -0.1 | -1.8 | -2.0 |
| AIWW Figure Eight Bridge | 2374595 | 193390 | 2.2 | 1.7 | -0.1 | -1.9 | -2.2 |

NOTE: These datums are based on a limited set of water level measurements in 2005 and have not been officially certified by NOAA.

## 4.3 Currents

Currents were measured by GBA during a spring tidal period on June 21, 2005 (Figure 4-2) using boat-mounted Acoustic Doppler Current Profilers (ADCPs). In the throat of the inlet and Green Channel, the currents were flood-dominated. In Nixon Channel, the currents appeared to be ebb-dominated.

- In the throat of the inlet, the peak currents were 3.2 feet/second during flood and 2.7 feet/second during ebb, with a principal axis of 319º/139º.
- In Green Channel, the peak currents were 3.0 feet/second during flood and 2.0 feet/second during ebb, with a principal axis of 341º/161º.
- In Nixon Channel, the peak currents were 1.7 feet/second during flood and 1.8 feet/second during ebb, with a principal axis of 280º/100º.

The current measurements by GBA were utilized to calibrate current, water level, and bathymetric change model for Rich Inlet. Flow patterns in Rich Inlet were then analyzed using the calibrated model. A review of the flow patterns appears in the Delft3D modeling study.

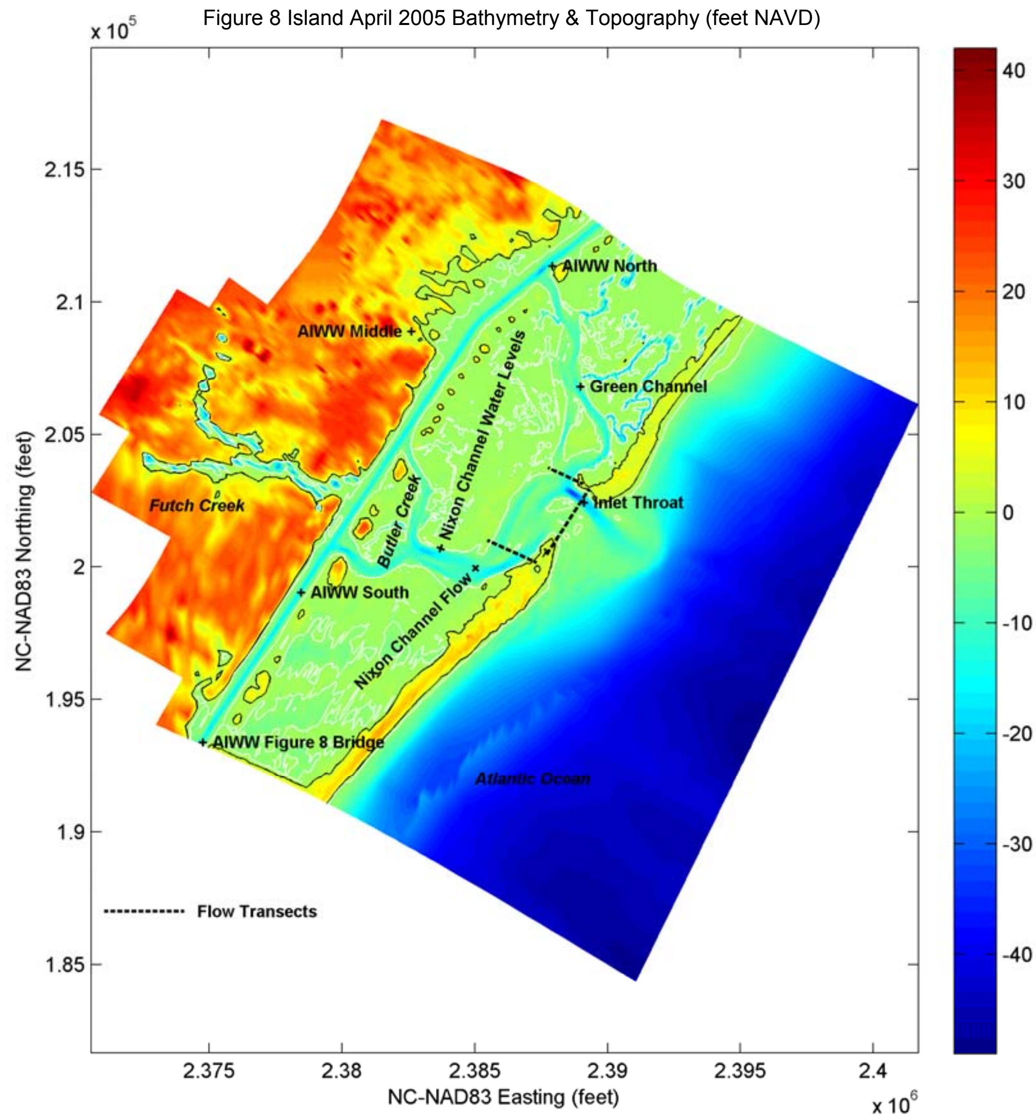



**FIGURE 4-1: Tide Gage and Current (Flow) Meter Locations in Rich Inlet.**

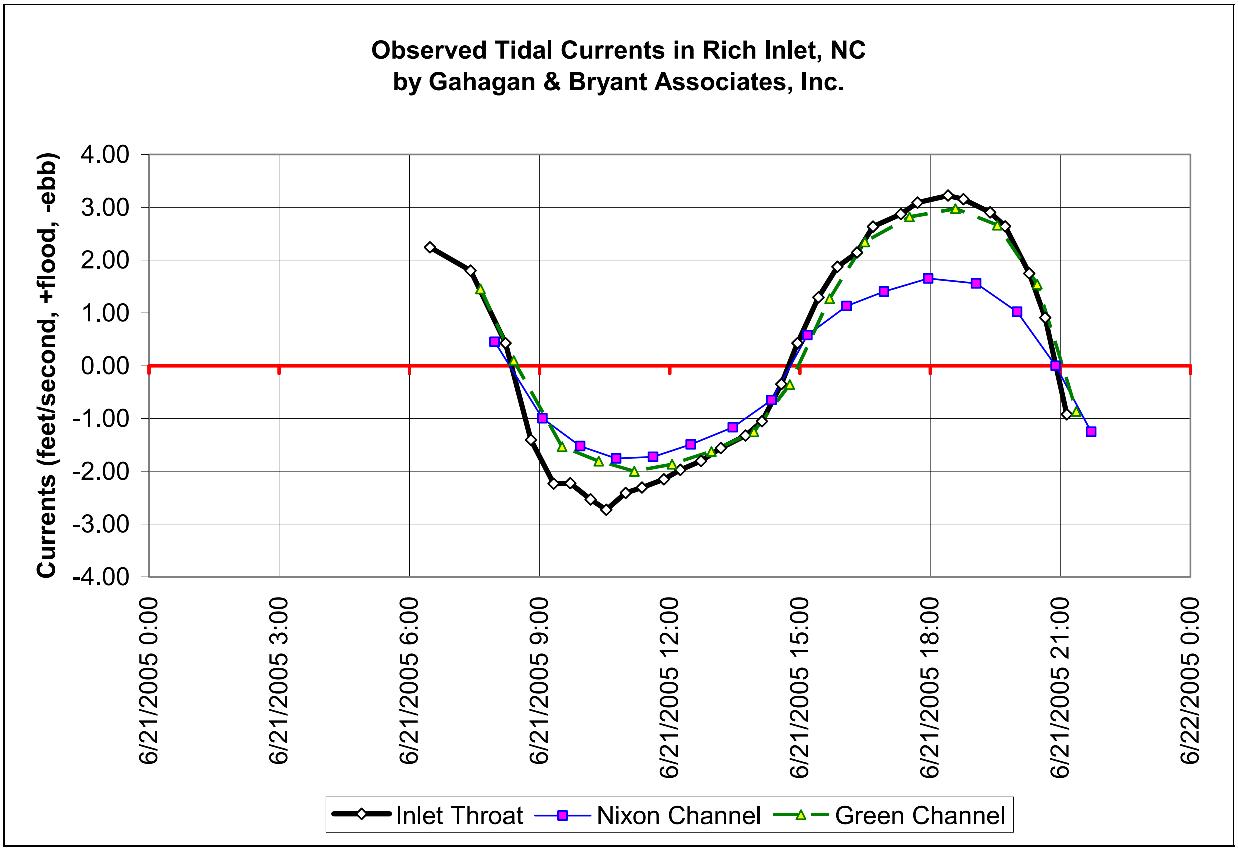



**FIGURE 4-2: Tidal Currents during Spring Tide, Rich Inlet, NC.**

## 4.4 Waves

Annual wave statistics at Figure Eight Island are based on the 2002-2005 wave observations at buoy OB3M (UNCW, 2007). The location of this gage is 34º06.133'N, 77º45.049'W at a depth of 52 feet (Figure 4-3). The root-mean-square wave height offshore is 3.3 feet, with a corresponding period and direction of 7.1 seconds and 139º (southeast). The principal direction bands are from the east-southeast and the southeast. The highest waves occur in February during the northeaster season and in August and September during hurricane season. During the summer, waves tend to approach from the south-southeast, driving the sediment transport towards the northeast. During the winter, waves tend to approach from the east-southeast, driving the sediment transport towards the southwest. Annual wave statistics appear in Tables 4-3 and 4-4 and in Figures 4-4 to 4-6.

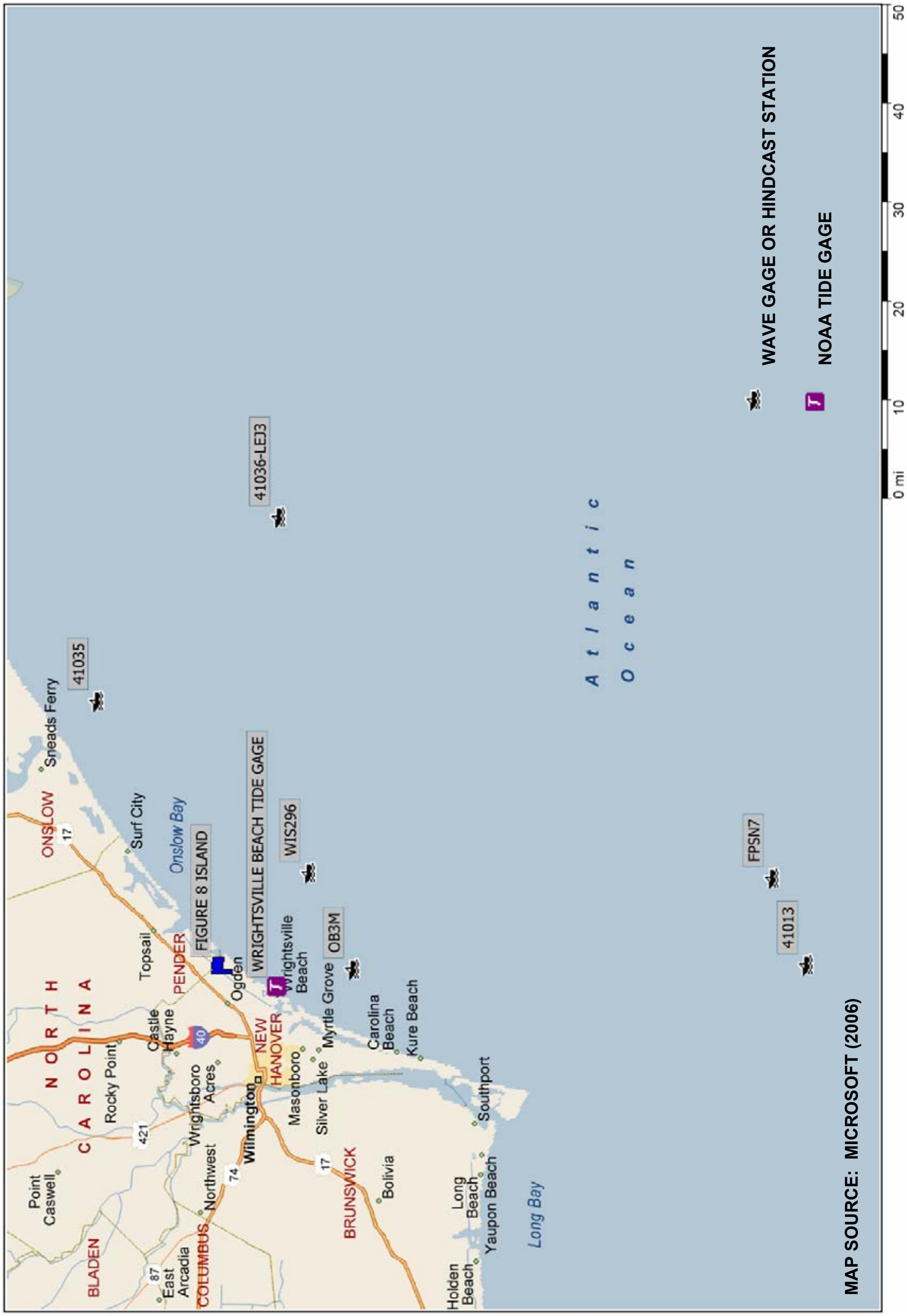



**FIGURE 4-3: Figure Eight Island, NC Wave Gages and Hindcast Stations.**

**TABLE 4-3**

**2002-2005 MONTHLY WAVE STATISTICS AT WAVE BUOY OB3M**
**FIGURE EIGHT ISLAND, NC**

| | Wave Height (feet) | | | Peak Wave Period (sec.) | | | Peak Wave Direction (deg.) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | RMS | Max | Mean | Max | of Highest | Avg. #1* | Avg. #2** | of Highest |
| January | 2.3 | 2.4 | 5.2 | 6.9 | 10.6 | 4.7 | 128 | 128 | 65 |
| February | 4.3 | 4.7 | 10.4 | 7.4 | 11.6 | 8.5 | 103 | 96 | 220 |
| March | 3.2 | 3.4 | 6.9 | 7.2 | 16.0 | 6.4 | 114 | 111 | 116 |
| April | 2.8 | 3.1 | 7.0 | 7.0 | 12.8 | 9.1 | 136 | 138 | 144 |
| May | 2.8 | 3.1 | 7.6 | 7.0 | 12.8 | 6.7 | 144 | 136 | 128 |
| June | 2.6 | 2.8 | 6.4 | 6.6 | 10.6 | 6.0 | 153 | 147 | 202 |
| July | 2.5 | 2.7 | 6.1 | 6.6 | 10.6 | 2.0 | 162 | 159 | 156 |
| August | 2.9 | 3.1 | 10.5 | 6.6 | 25.6 | 8.0 | 140 | 134 | 139 |
| September | 3.9 | 4.1 | 8.1 | 8.0 | 18.2 | 16.0 | 124 | 124 | 147 |
| October | 3.1 | 3.3 | 5.8 | 8.1 | 16.0 | 5.8 | 112 | 113 | 118 |
| November | 2.8 | 3.1 | 7.7 | 7.5 | 14.2 | 8.5 | 119 | 119 | 153 |
| December | 3.0 | 3.4 | 8.5 | 6.8 | 18.2 | 8.0 | 127 | 125 | 103 |
| AVG. | 3.0 | 3.3 | 10.5 | 7.1 | 25.6 | 8.0 | 134 | 127 | 139 |

Notes: * Average direction #1 is a simple average of the wave direction.
** Average direction #2 is the direction of the average wave energy flux.

**TABLE 4-4**

**2002-2005 DIRECTIONAL WAVE STATISTICS AT WAVE BUOY OB3M**
**FIGURE EIGHT ISLAND, NC**

| Angle | % | Wave Height (feet) | | | Peak Wave Period (sec.) | | |
|---|---|---|---|---|---|---|---|
| Band (deg.) | Occur. | Mean | RMS | Max | Mean | Max | of Highest |
| 0 | 0.3 | 2.8 | 3.1 | 7.7 | 3.6 | 4.9 | 4.9 |
| 22.5 | 3.4 | 3.3 | 3.7 | 8.8 | 6.7 | 18.2 | 7.5 |
| 45 | 1.7 | 3.3 | 3.5 | 6.8 | 4.8 | 9.8 | 5.5 |
| 67.5 | 5.3 | 3.7 | 4.0 | 8.0 | 5.7 | 16.0 | 6.4 |
| 90 | 14.0 | 3.4 | 3.7 | 7.9 | 6.9 | 16.0 | 7.5 |
| 112.5 | 17.8 | 2.9 | 3.2 | 8.6 | 8.1 | 18.2 | 8.0 |
| 135 | 17.8 | 2.9 | 3.2 | 10.5 | 8.5 | 18.2 | 8.0 |
| 157.5 | 15.1 | 2.9 | 3.2 | 8.1 | 7.5 | 18.2 | 16.0 |
| 180 | 13.3 | 2.8 | 3.0 | 7.9 | 6.5 | 25.6 | 7.5 |
| 202.5 | 8.6 | 2.6 | 2.8 | 6.4 | 5.3 | 16.0 | 6.0 |
| 225 | 1.5 | 2.8 | 3.1 | 10.4 | 4.8 | 16.0 | 8.5 |
| 247.5 | 0.1 | 2.5 | 2.6 | 3.5 | 4.1 | 7.1 | 7.1 |
| 270 | 0.1 | 3.2 | 3.5 | 5.9 | 4.7 | 5.5 | 4.7 |
| 292.5 | 0.1 | 2.8 | 2.9 | 4.1 | 4.8 | 8.5 | 3.6 |
| 315 | 0.2 | 3.7 | 3.9 | 6.1 | 4.2 | 6.4 | 6.4 |
| 337.5 | 0.3 | 2.7 | 2.9 | 6.1 | 5.3 | 18.2 | 5.3 |


**FIGURE 4-4: Directional Wave Statistics, Wave Buoy OB3M, Figure Eight Island, NC.**

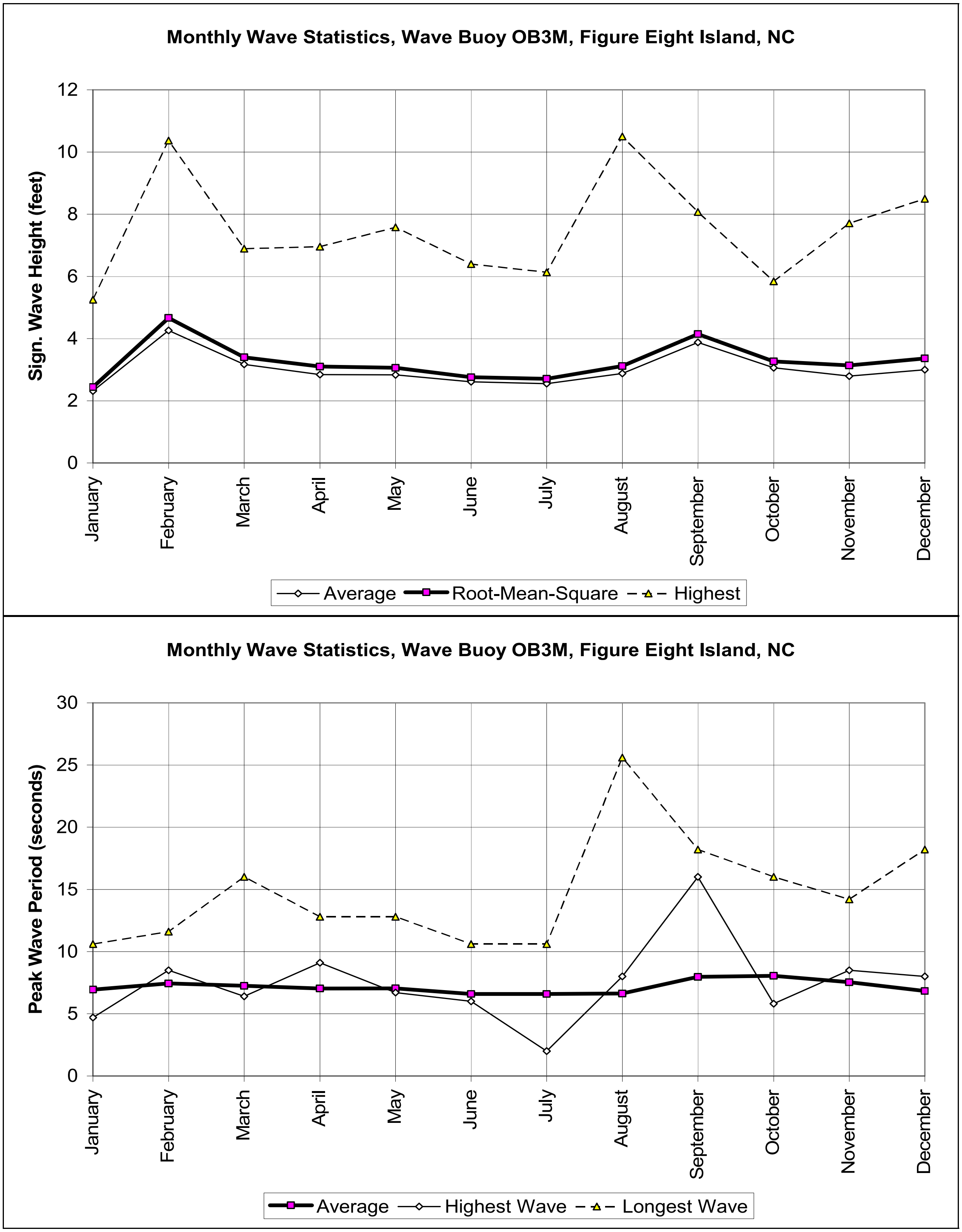



**FIGURE 4-5: Monthly Wave Height and Wave Period, Figure Eight Island, NC.**

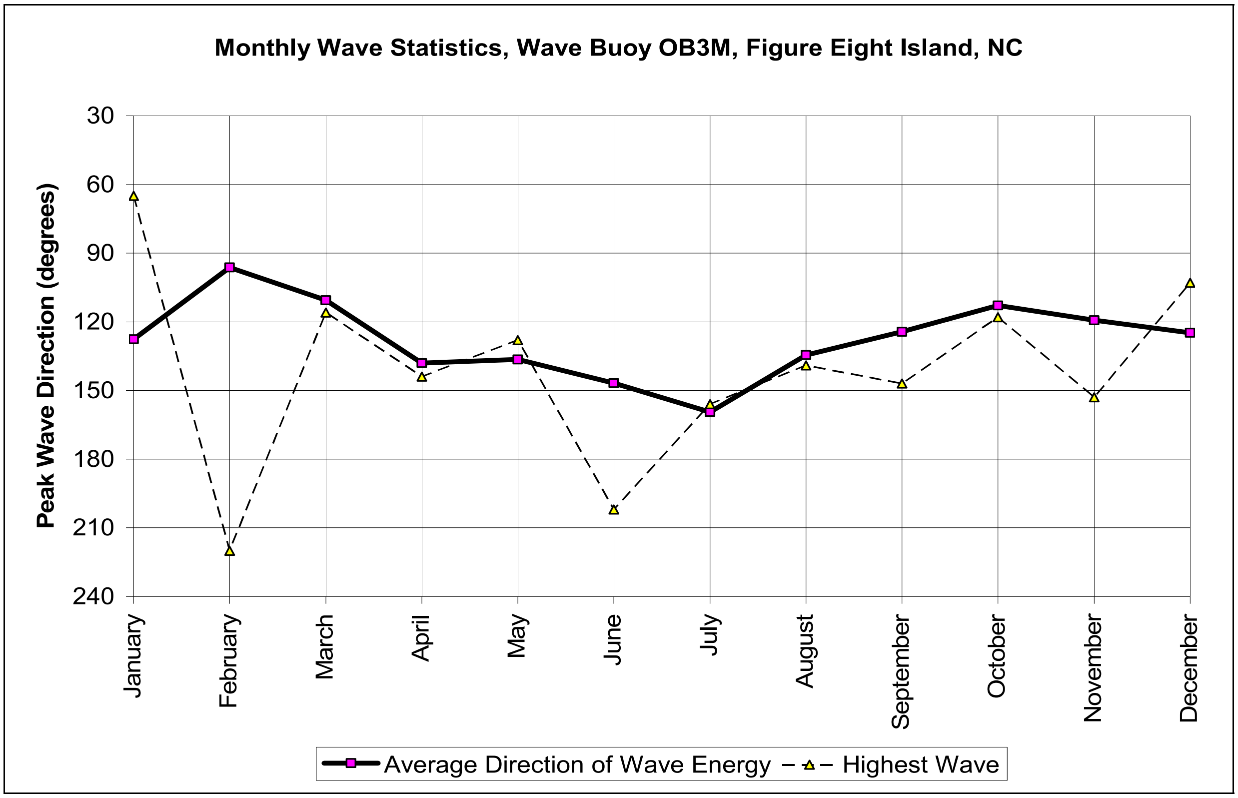



**FIGURE 4-6: Monthly Wave Direction, Figure Eight Island, NC.**

For numeric modeling purposes, wave conditions during storms were based on the 20 year wave hindcast record at Wave Information System (WIS) Station 296 (Figure 4-3). Wave conditions during severe storms were estimated in terms of return period. The return period represents the chance of a given wave event being exceeded in any given year. For example, the 20 year wave has a 1 on 20 chance of being exceeded in any given year. To delineate the wave height and wave period versus return period, the 20 highest wave events were taken from the wave record. A Weibull distribution was then estimated for the highest 20 wave events. The resulting wave heights and wave periods given the return period appear in Figure 4-7 and Table 4-5.

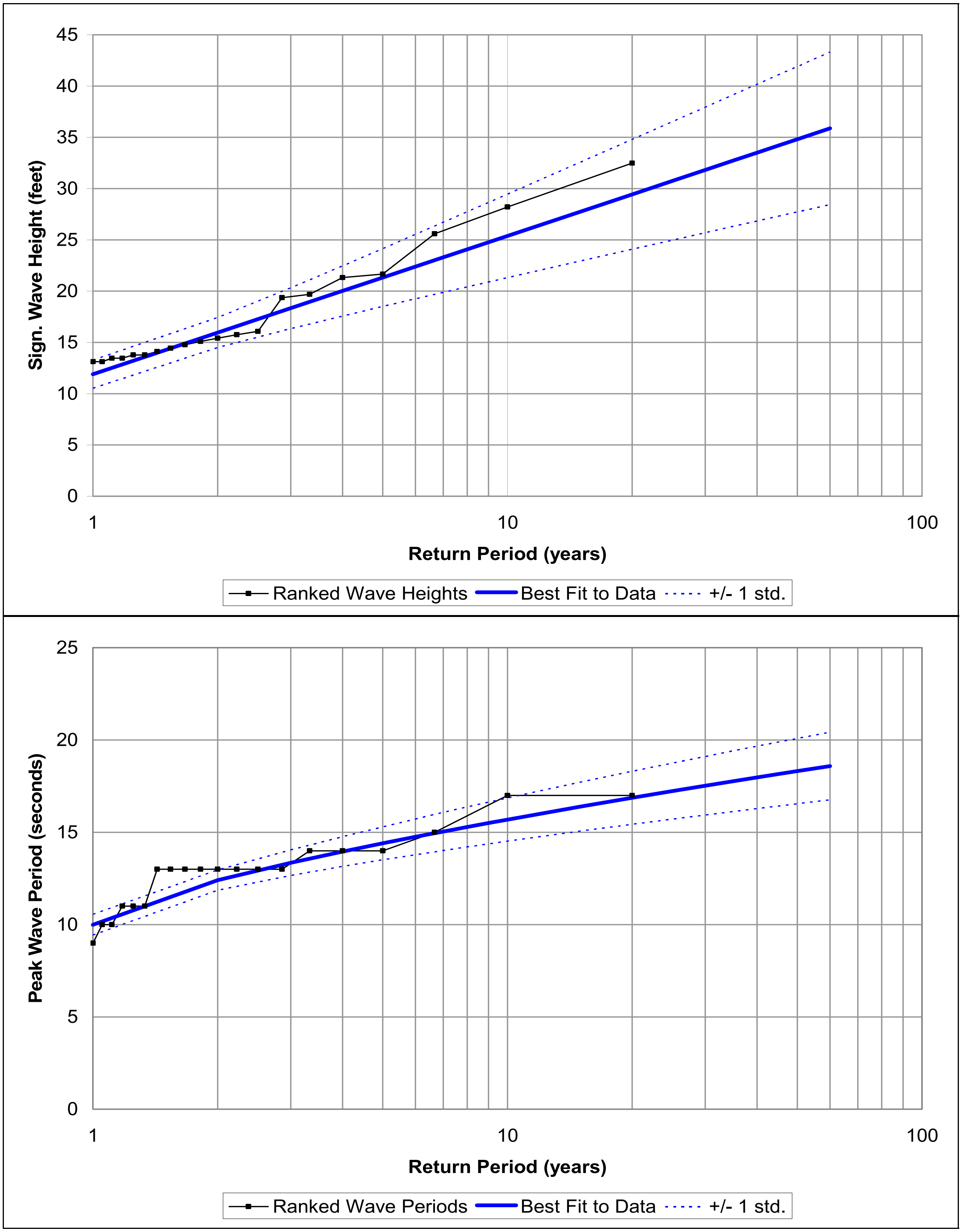



**FIGURE 4-7: Storm Wave Statistics, Hindcast Station WIS296, Figure Eight Island, NC.**

**TABLE 4-5**

**1980-1999 STORM WAVE STATISTICS**
**HINDCAST STATION WIS296**
**FIGURE EIGHT ISLAND, NC**

| Return Period (years) | Wave Height $H_{mo}$ (feet) | +/- $\sigma$ | Wave Period $T_p$ (sec.) | +/- $\sigma$ |
|---|---|---|---|---|
| **1** | **11.9** | **1.4** | **10.0** | **0.6** |
| 2 | 16.0 | 1.5 | 12.4 | 0.5 |
| 3 | 18.3 | 2.0 | 13.4 | 0.7 |
| 4 | 20.0 | 2.4 | 14.0 | 0.8 |
| **5** | **21.3** | **2.8** | **14.4** | **0.9** |
| 6 | 22.4 | 3.1 | 14.8 | 1.0 |
| 7 | 23.3 | 3.4 | 15.0 | 1.0 |
| 8 | 24.1 | 3.7 | 15.3 | 1.1 |
| 9 | 24.8 | 3.9 | 15.5 | 1.1 |
| **10** | **25.4** | **4.1** | **15.7** | **1.2** |
| 15 | 27.8 | 4.8 | 16.4 | 1.3 |
| **20** | **29.4** | **5.4** | **16.9** | **1.4** |
| 25 | 30.7 | 5.8 | 17.2 | 1.5 |
| 30 | 31.8 | 6.1 | 17.5 | 1.6 |
| 35 | 32.7 | 6.4 | 17.8 | 1.6 |
| 40 | 33.5 | 6.7 | 18.0 | 1.7 |
| 45 | 34.2 | 6.9 | 18.2 | 1.7 |
| **50** | **34.8** | **7.1** | **18.3** | **1.8** |
| 60 | 35.9 | 7.4 | 18.6 | 1.8 |

## 4.5 Storm Surge

Storm surge is defined as the rise of the sea surface above its astronomical tide level due to storm forces. The elevation that the storm surge reaches is known as the storm stage. The increase elevation is attributable to a variety of factors, including waves, wind shear stress, and atmospheric pressure. Storm stages are an important factor governing the performance of a beach fill during storms.

The Federal Emergency Management Agency (FEMA) released a Flood Insurance Study on April 3, 2006 for New Hanover County, North Carolina. The study detailed the storm stage elevations for 10, 50, 100, and 500 year storms. Oceanfront storm stages appear in Table 4-6 and Figure 4-8. The numerical models used in this study utilize offshore water levels as an input and calculate wave setup as an output. Accordingly, the stage values in Table 4-6 do not include wave setup. Detailed discussions of the SBEACH and Delft3D models appear in later sections of this report.

**TABLE 4-6**

**OCEAN STORM STAGES**
**FIGURE EIGHT ISLAND, NC**

| FEMA Transect | Location | Storm Stage in feet NAVD given return period in years (excluding wave setup) | | | |
|---|---|---|---|---|---|
| | | 10 | 50 | 100 | 500 |
| 58 | Approximately 2,430' south of intersection of Pipers Neck Rd. and Sounds Pt. | 5.7 | 8.7 | 9.9 | 12.4 |
| 59 | Approximately 645' southeast of intersection of Pipers Neck Rd. and Little Neck Rd. | 5.7 | 8.7 | 9.9 | 12.4 |
| 60 | Approximately 290' southeast of intersection of Saltmeadow Rd. and S. Beach Rd. | 5.7 | 8.7 | 9.9 | 12.4 |
| 61 | Approximately 720' northeast of intersection of S. Beach Rd. and Banks Rd. | 5.7 | 8.7 | 9.9 | 12.4 |
| 62 | Approximately 960' northeast of intersection of S. Beach Rd. and Backfin Pt. | 5.7 | 8.7 | 9.9 | 12.4 |
| 63 | Approximately 590' east of intersection of N. Beach Rd. and Bayberry Pl. | 5.5 | 8.6 | 9.9 | 12.3 |
| 64 | Approximately 1610' northeast of intersection of N. Beach Rd. and Salters Rd. | 5.4 | 8.5 | 9.8 | 12.3 |
| 65 | Approximately 1250' southwest of intersection of N. Beach Rd. and Clamdigger Point Rd. | 5.3 | 8.5 | 9.8 | 12.3 |
| 66 | Approximately 830' southeast of intersection of Surf Ct. and N. Beach Rd. | 5.3 | 8.5 | 9.8 | 12.3 |
| 67 | Approximately 520' east of intersection of N. Beach Rd. and Oyster Catcher Rd. | 5.3 | 8.5 | 9.8 | 12.3 |
| | Minimum | 5.3 | 8.5 | 9.8 | 12.3 |
| | Average | 5.5 | 8.6 | 9.9 | 12.4 |
| | Maximum | 5.7 | 8.7 | 9.9 | 12.4 |

Source: FEMA (2006).

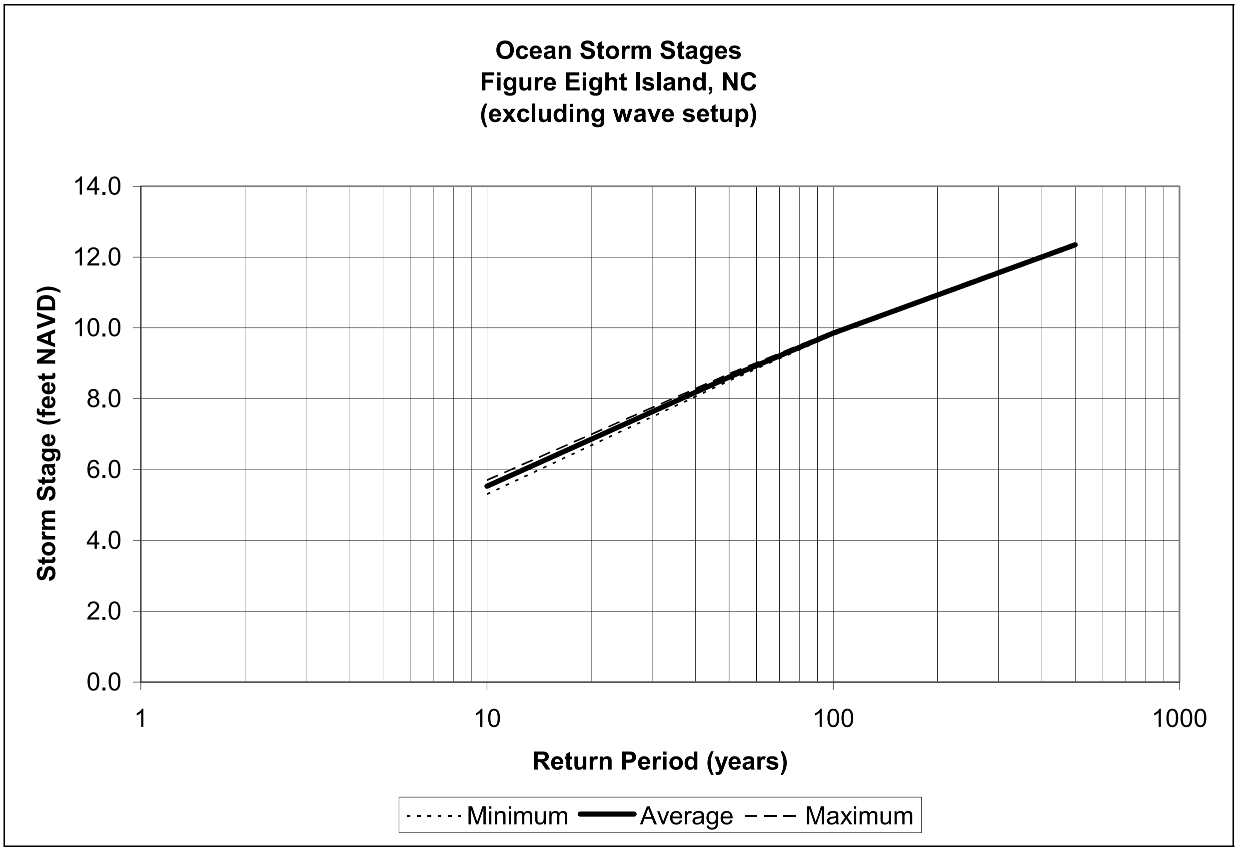



**FIGURE 4-8: Ocean Storm Stages, Figure Eight Island, NC.**

## 4.6 Depth of Closure

The depth of closure is defined as the "depth beyond which repetitive profile or topographic surveys (collected over several years) do not detect significant vertical sea bed changes. This is generally considered the seaward limit of littoral transport" (Morang and Szuwalski, 2003). The depth of closure is typically estimated by either comparing historic profiles and observing where the profiles close (pinch out and have no elevation difference) or using empirical equations, such as the ones developed by Hallermeier (1978) or Birkemeier (1985).

Historic profiles of Figure Eight Island were compared for surveys taken in October 2004, April and October 2005, and April 2006. The profiles appeared to close at an average depth of -24 feet NAVD, with closure depths ranging from -17 ft to -31 ft NGVD. This estimate was consistent with the established depth of closure for Topsail Beach (Figure 4-3), which was also -24 feet NAVD (USACE, 2006).

Empirical equations were also used to estimate the depth of closure for the project area. The Hallermeier (1978) and Birkemeier (1985) empirical equations are based on the significant wave event that is exceeded 12 hours per year ($H_e$ and $T_e$). Hallermeier's equation is Equation 1, while Birkemeier's equation is shown as Equation 2.

Hallermeier's equation:

$$h_* = 2.28H_e - 68.5\left(\frac{H_e^{\ 2}}{gT_e^{\ 2}}\right)$$ [Equation 1]

Birkemeier's equation:

$$h_* = 1.75H_e - 57.9\left(\frac{H_e^{\ 2}}{gT_e^{\ 2}}\right)$$ [Equation 2]

The 12-hour wave event at WIS Station 296 (between 1980 and 1999) was found to have a significant wave height ($H_e$) of 15.8 feet and a period ($T_e$) of 12.5 seconds. The ACES linear wave transformation program suggests that this wave is transformed to a 21.9-foot wave near the shoreline. Application of Hallermeier's equation suggests that the depth of closure is -43.4 feet, MSL while Birkemeier's equation suggests that the depth of closure is -32.8 feet, MSL.

Based on experience, the depths of closure based on these two equations appear to be an overestimate of the depth to which sediment would be transported following a beach nourishment project. The established depth of closure for Topsail Beach (USACE, 2006) is the same as the survey-based value for Figure Eight Island. Accordingly, -24 feet NAVD has been chosen as the depth of closure for the development of this project.

## 4.7 Relative Sea Level Rise

The rate of sea level rise applicable to Figure Eight Island was determined from the average of sea level change rates observed at Sewells Point, VA (0.0145 ft/yr), Beaufort, NC (0.0084 ft/yr), and Charleston, SC (0.0103 ft/yr). The observed sea level trends are available from: http://tidesandcurrents.noaa.gov. The period of sea level observations used to establish these rates ranged from 85 years for Charleston, SC to 53 years for Beaufort, NC. The average rate of rise for these three stations is 0.0111 ft/yr. The impacts of sea level rise on shoreline changes along Figure Eight Island due to a relative rise in sea level of 0.0111 ft/yr were based on the well known Brunn Rule (Brunn, 1962). Per Brunn theorized that as sea level rises, the beach profile attempts to reestablish the same bottom depths relative to the surface of the sea that existed prior to the rise in sea level. The quantity of material needed to reestablish the beach profile must be derived from erosion of the shore. This theory is expressed by the equation:

$$\Delta x = ab/(e+d)$$

where:

$\Delta x$ = rate of shoreline recession due to sea level rise.
e = elevation of the beach berm (+ 6 feet NAVD).
d = limiting depth between predominant nearshore and offshore material transport characteristics (-24 feet NAVD).
a = rate of sea level rise (0.0111 ft/yr)
b = distance from the initial shoreline to the limiting depth (average about 2,000 feet for Figure Eight Island).

For Figure Eight Island, the rate of shoreline erosion ($\Delta x$) associated with a sea level rise rate of 0.0111 ft/yr is equal to about 0.7 ft/year.

## 4.8 Native Beach Grain Size

To evaluate the materials presently on the beach, sand samples were collected in September 2007 from profiles F80+00, 10+00 (F120+00), 50+00 (F160+00), and 90+00 (F200+00) on Figure Eight Island. Due to several beach fill projects constructed along Figure Eight Island prior to sampling, these samples did not represent the “native materials” as defined by the North Carolina Technical Standards for Beach Fill Projects (15A NCAC 07H.0312). After discussion with State representatives, it was decided that sampling of the adjacent barrier island, Hutaff Island would be necessary to determine native composites. Additional samples were taken from profiles 160+00 (H1), H2, and H3 on Hutaff Island in September, 2007, along with the samples collected on Figure Eight Island. All profiles were sampled at the following locations:

- Dune
- Toe Of Dune
- Mid-Berm
- +2.0 to +3.0 feet NAVD
- Mean High Water
- Mean Tide Level
- Mean Low Water
- -6 feet NAVD
- -8.8 feet NAVD
- -11.6 feet NAVD
- -14.4 feet NAVD
- -17.2 feet NAVD
- -20 feet NAVD

The existing “beach” composites on Figure Eight Island are summarized in Table 4-7, along with the native composites on Hutaff Island. The locations of each sand sample appear in Figure 4-9.

**TABLE 4-7**

**EXISTING BEACH COMPOSITES**
**FIGURE EIGHT ISLAND AND**
**HUTAFF ISLAND, NC**

| PROFILE | Mean Grain Size (mm) | Mean Grain Size (Φ) | Sorting (Φ) | % Silt | % Carbonate |
|---|---|---|---|---|---|
| F80+00 | 0.19 | 2.40 | 0.66 | 0.96 | 7.9 |
| 10+00 (F120+00) | 0.18 | 2.45 | 0.55 | 1.03 | 5.4 |
| 50+00 (F160+00) | 0.18 | 2.45 | 0.50 | 1.13 | 4.8 |
| 90+00 (F200+00) | 0.18 | 2.47 | 0.46 | 1.04 | 5.9 |
| **Figure Eight Island December 2007 "Beach" Composite** | **0.18** | **2.44** | **0.55** | **1.04** | **6.0** |
| 160+00 (H1) | 0.20 | 2.33 | 0.64 | 0.89 | 6.9 |
| H2 | 0.19 | 2.41 | 0.59 | 0.97 | 5.9 |
| H3 | 0.24 | 2.03 | 1.16 | 1.14 | 17.0 |
| **Hutaff Island December 2007 Native Composite** | **0.21** | **2.26** | **0.85** | **1.00** | **9.9** |

The native material on Hutaff Island is fine sand and exhibits a mean grain size of 0.21 mm, a sorting value of 0.85Φ, a carbonate content of 10%, and a low silt content of 1%. The "beach" material on Figure Eight Island is also fine sand, and exhibits a mean grain size of 0.18 mm, a sorting value of 0.55Φ, a carbonate content of 6%, and a silt content of 1%. The "beach" material on Figure Eight Island is slightly finer than the truly native material on Hutaff Island. However, the difference between the two composites is not large, and suggests that the fill placed in 2006 has mixed with the native material. A more detailed discussion of the materials presently on the beach appears in the Geotechnical Investigation for this study.


**FIGURE 4-9: December 2007 Sand Samples, Figure Eight Island and Hutaff Island, NC.**

## 4.9 Inlet Grain Size

In general, the material in Rich Inlet is fine sand. Based on the geotechnical information, the mean grain sizes of the material in the dredge cuts for Rich Inlet range from 0.18 to 0.30 mm, with sorting values ranging from 0.44 to 1.16Φ, and silt contents on the order of 1%. The composite for the dredge cuts has a mean grain size of 0.24 mm, a sorting value of 0.83Φ, and a silt content of 1%. A more detailed discussion of the materials in the dredge cuts appears in the final Geotechnical Investigation for this study.

## 4.10 Tidal Prism of Rich Inlet

Several estimates of the tidal prism have been developed for Rich Inlet (Table 4-8). Two sets of estimates appeared in a study by Cleary and Knierim (2003). One set was based on an Acoustic Doppler Current Profiler (ADCP) survey, and the second set was based on empirical relationships between tidal range and tidal prism.

**TABLE 4-8**

**RICH INLET TIDAL PRISM ESTIMATES**
**FIGURE EIGHT ISLAND, NC**

| SOURCE / METHOD | TIDAL PRISM THROUGH INLET THROAT (cubic feet) | | | | | |
|---|---|---|---|---|---|---|
| | SPRING TIDES | | AVG. TIDES | | NEAP TIDES | |
| | FLOOD | EBB | FLOOD | EBB | FLOOD | EBB |
| Cleary & Knierim (2003) | | | | | | |
| ADCP Survey | 797,000,000 | 690,000,000 | 603,000,000 | 562,000,000 | 329,000,000 | 430,000,000 |
| Empirical Relationships | 645,000,000 | 652,000,000 | 469,000,000 | 434,000,000 | 318,000,000 | 247,000,000 |
| Gahagan & Bryant (2005) Measurements | 1,101,000,000 | 560,000,000 | N/A | N/A | N/A | N/A |
| Delft3D Model with Waves April 2006 Conditions | N/A | N/A | 653,000,000 | 697,000,000 | N/A | N/A |

Tidal prism estimates were also estimated based on a later ADCP survey by Gahagan & Bryant (2005). The depth-averaged currents (Figure 4-2) were combined with concurrent water levels and survey data (Figure 4-1) to evaluate the flow rate through the inlet throat in cubic feet per second. Flow rates were then integrated over the flood and ebb cycles shown in Figure 4-1. A final set of tidal prism estimates was based on the Delft3D modeling results. The tidal prism estimates varied widely. However, based on the values in Table 4-8, the average tidal prism was on the order of 560,000,000 cubic feet. A further discussion of the tidal prism appears in the Delft3D modeling study.

## 5.0 CHANNEL EVOLUTION

Erosion and accretion along relatively stable inlets such as Rich Inlet are related to complex cyclical changes in the shape of the ebb-tidal deltas. Cycles are associated with the repositioning and realignment of the ebb channel and corresponding position and size changes of the marginal flood channels and where swash bars welded onto the adjacent shorelines (FitzGerald, 1984; Cleary, 1994, 1996, and 2002; Cleary and Marden, 1999; Cleary et al., 1989).

Rich Inlet drains an extensive estuary filled with tidal marsh where two large tidal creeks, Nixon and Green Channels, connect the inlet to the Atlantic Intracoastal Waterway (AIWW). It is an example of a relatively stable inlet where the repositioning and realignment of the ebb channel leads to dramatic erosion on one or both adjacent beaches. Erosion occurs as the shape of the offshore sand shoals changes thereby affecting impact of incoming waves on the nearby beaches. Historic map and geomorphic data indicate the inlet has been a relatively stable feature over the past century. The large drainage area that includes portions of the bar-built lagoon and Pages Creek estuary enhances the inlet's stability.

A GIS-based analysis of historic aerial photographs dating from 1938 to 2003 was undertaken by Cleary and Jackson (2004) to quantify shoreline changes, their connection to the inlet's migration, and the system changes of the inlet. Cleary provided an update of this analysis which appears in Sub-Appendix A.

### 5.1 Historic Channel Alignment (Cleary and Jackson, 2004)

> "The recent movement of the ebb (entrance) channel has been confined to a ~0.30 mile wide pathway. The ebb-tidal delta is situated on Oligocene siltstone that crops out along the ebb delta's outer margin in water depths of 30 feet. The width of the inlet throat reached a maximum of 2,673 feet in October of 1989 and a minimum of 920 feet in February of 2001. The average with the inlet throat since 1938 was 2,000 feet.
>
> Since 1938, the position of the ebb (entrance) channel has remained within a 1,600 foot wide migration corridor, indicating that Rich Inlet has been relatively stable. Through the period from 1938 to 2003, the orientation of the ebb channel across the outer portion of the ebb-tidal delta has fluctuated between 83˚ and 181˚. Between 1938 and 1993, the ebb channel was oriented predominately in a southeasterly direction between 112˚ and 181˚ before realigning to a more easterly orientation of 103˚ in 1996. The ebb channel's alignment and position prior to the mid-1990s promoted the development of a one-mile long zone of accretion along the Figure Eight Island oceanfront immediately south of the inlet. During the period from 1993 to 1996, the ebb channel rapidly migrated 1,056 feet northeast at a rate of 308 feet per year. Between August 1996 and February 1998, the ebb channel shifted 147 feet further to the northeast before reversing its migration direction to the southwest in June 1998. Inspection of aerial photographs shows that between June 1998 and February 2002, the ebb channel migrated a distance of 588 feet to the southwest at a rate of 160 feet per year.

While the ebb channel tracked to the northeast between March 1993 and February 1998, the northern spit of Figure Eight Island elongated, dramatically reducing the inlet's width. Although the migration direction changed to the southeast in June 1998, the orientation of the ebb channel continued to be deflected in a northeasterly direction before reaching alignment of 83˚ in October 2000. A breach of the ebb-tidal delta occurred in the latter part of 2000 that resulted in a shore-normal repositioning of the ebb channel. Between February 2001 and March 2003, the outer segment of the ebb channel was continually deflected from its 156˚ alignment in early 2001 to an alignment of 190˚ by early 2003. During late 2003 and early 2004, the ebb channel was reoriented to a shore normal alignment.

Previous studies have shown that the position and orientation of the ebb channel has controlled the shape and ebb tidal delta and ultimately dictates the shoreline changes along the adjacent oceanfront shorelines of Figure Eight Island.

In order to reverse the current erosion trend and promote accretion along the northern oceanfront of Figure Eight Island, the ebb channel must assume a position that approximates the location of the ebb (entrance) channel imaged in 1980 and maintain a near shore-normal orientation of ~145 degrees. For this repositioning to occur the ebb channel must migrate ~1,300 feet to the southwest."

## 5.2 Location of Ebb Shoal Apex (Cleary and Jackson, 2004)

"The position and alignment of the ebb channel has controlled the symmetry of the ebb-tidal delta and its apex. The changes in the shape of the ebb-tidal delta and in the position of its apex (seaward protrusion) since 1938 are depicted in Figure [5-1]…. Changes in the position of the apex, with time, are a function of the complex interplay of ebb channel (inlet) migration and the deflection of the outer ebb channel. Storms are also thought to contribute to the observed changes in the shape of the ebb-tidal delta. Regardless of the mechanism, the position of the ebb-tidal delta's apex plays a major role in the controlling the manner in which waves impact the oceanfront shorelines in the immediate vicinity of the inlet.

The location of the apex generally coincides with the point where the ebb channel crosses the periphery of the ebb-tidal delta. Deflection of the ebb channel since 1938 has caused a shift in the position of the apex and shape change of the ebb tidal delta across a ~5,100 foot wide zone. As ebb channel migration occurred, the entire offshore shoal complex was continuously being reconfigured along the with adjacent barrier shorelines as they responded to the changes in wave approach and sand supply. The current ebb-tidal delta shape has controlled the erosion since 1997. The zone of maximum erosion along the oceanfront shorelines has generally shifted eastward through time as the ebb channel has migrated to the northeast. The northeasterly shift of the channel has not only dictated the shape of the offshore shoals that afford protection for the end of the island, but simultaneously this shift has controlled the location where large swash bar complexes attach to the shoreline.

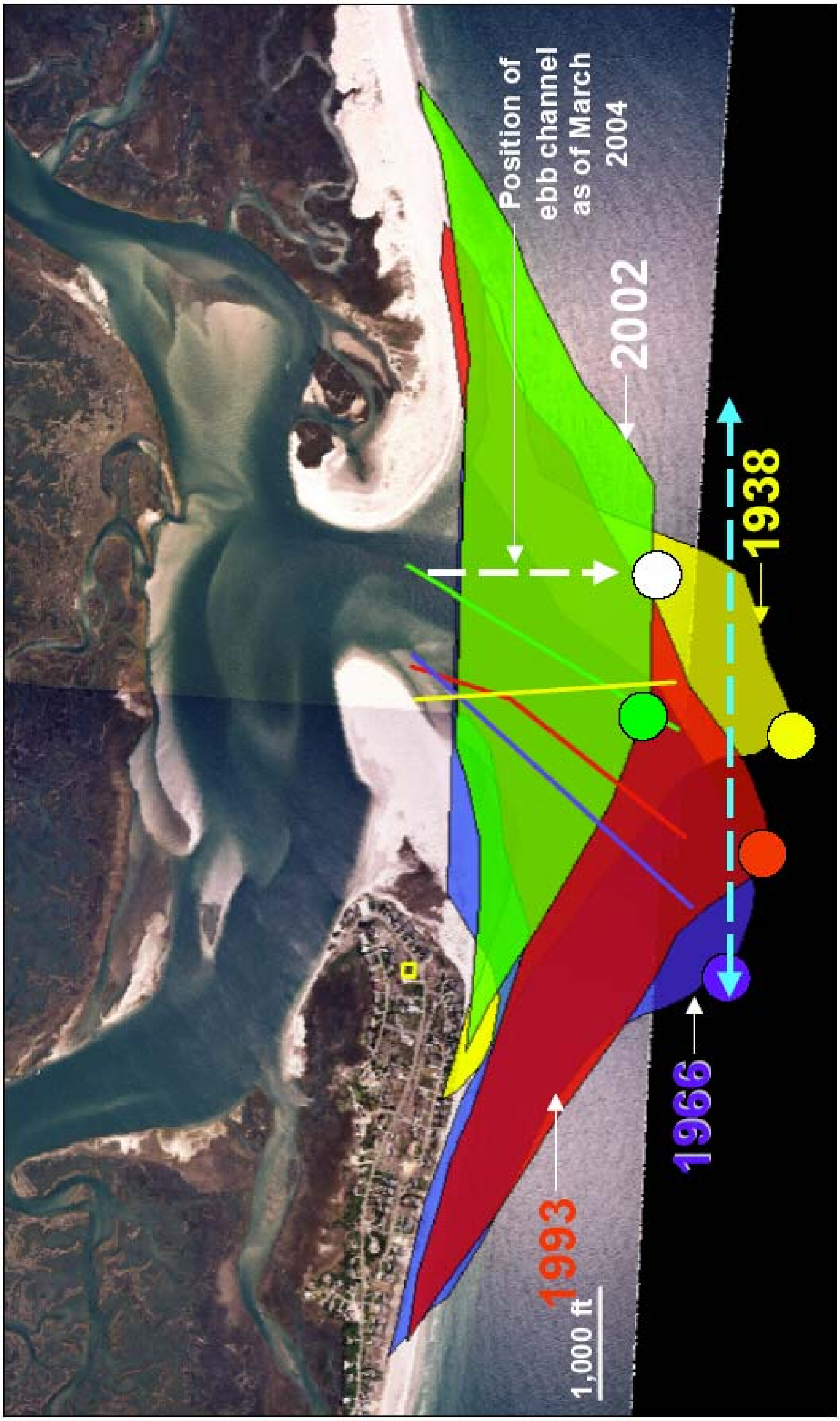



FIGURE 5-1: Aerial photograph (March 2002) with shapes of ebb deltas (as defined by zone of breaking waves), ebb channel positions and apex of ebb deltas (colored dots). The white arrow and dot represent approximate position of the ebb channel and apex in March 2004. Dashed light blue arrow delineates the width of the zone of deflection of the ebb delta apex (dots) (Cleary and Jackson, 2004).

A repositioning of the ebb channel toward Figure Eight Island will lead to a seaward shift and repositioning of the apex to the southwest. The consequences of this net change will reverse the erosion trend that has characterized the oceanfront since 1997.

Any future modification of the inlet should consider the ebb channel's optimum position alignment and the consequent ebb-tidal delta symmetry and related potential shoreline changes. The most felicitous ebb channel position and alignment for shoreline accretion on Figure Eight Island is a configuration where the ebb channel is shore normal and is positioned along the southern portion of its migration pathway, ~1,300 feet to 1,500 feet southwest of its current potion. Any plans that result in a substantial deviation from the above configuration will lead to increased shoreline retreat along a position of the erosion hot-spot. If and when the ebb channel attains the aforementioned position, the ebb-tidal delta will begin to reconfigure and thereby cause a southwesterly shift in large volumes of sand and in the wave sheltering effects of the offshore shoal complex. It must be understood that it is likely there will be a lag effect in terms of the movement of the ebb channel and the timing of the positive impacts along the oceanfront. The lag is primarily due to the time needed for the remobilization of the enormous volume of sediment retained in the ebb-tidal delta that currently lies northeast of the erosion hot-spot. There is a high probability that a breach across the undeveloped spit could occur that will shorten the time lag considerably. The morphology of the inlet depicted on recent photographs and observations made during recent over-flight indicate that the spit is highly vulnerable to breaching when it is narrow."

## 6.0 SHORELINE CHANGE ANALYSIS

The Figure Eight Island shoreline is a dynamic feature in a constant state of flux due to changes in wave energy and sediment supply. When viewed in terms of decades or on the century scale, a complex set of factors, which operate in concert, have dictated shoreline change along both the oceanfront and inlet shorelines. Under the combined influence of cumulative storm impacts, waves, and inlets, the island has generally become erosional, although certain sections of the island accrete. Sea level rise also contributes to the erosion rates along the island. However, in comparison to the other forces driving erosion, the contribution of sea level rise, which is estimated to be around -0.7 ft/yr, is minor. Much of the northern section of Figure Eight Island is characterized by multiple sets of dune ridges that reflect the buildup of the beach that is related to the influence of Rich Inlet. The presence of large intact dunes provides protection from flooding due to increased water levels and overtopping during storms.

During the late 1990s the complex interplay between the northeasterly migration of the channel and the continuing realignment of its outer segment has resulted in a shift of the breakwater effect of the ebb-tidal delta and a repositioning of it to the northeast. Consequently, the Figure Eight Island oceanfront was no longer afforded protection from wave attack. As a result, the northern 4,500 foot segment of the oceanfront, which has a history of net accretion, began to experience severe erosion.

In the Fall of 2000, an ebb delta breaching event occurred that repositioned the ebb channel and initiated a southwestward trek of the inlet and promoted erosion along the downdrift Figure Eight

Island shoreline. Between 2001 and 2003 the shoreline retreat averaged ~10 feet. In an effort to mitigate the chronic recession, 350,000 cubic yards of fill material was placed along the erosion zone and the area to the south in February and March 2001 (Cleary and Jackson, 2004). Much of the beach fill was lost by November 2001. In late 2001, erosion continued and reached critical proportions and as a last resort, large sand bags were placed along a number of the endangered homes in the area. The entirety of this shoreline stretch is now armored with a wall of sand bags. Additional fill was placed along this area in 2005 and 2006 (GBA, 2006). However, the shoreline response through March 2008 was similar to the shoreline change after the 2001 project (Figure 6-1).

**FIGURE 6-1: North End of the Sandbagged Area, 4-7 Inlet Hook Road, March 18, 2008.**

Oceanfront shoreline changes on Figure Eight Island since the October 1999 Light Detection and Ranging (LIDAR) survey by NOAA appear in Figure 6-2 and Table 6-1. The effect of beach fill (Table 6-2) was removed from these shoreline changes. In general, the northern and southern ends of the island erode, while the middle of the island accretes. Aside from the various beach fills, the northern end of the island (profiles 40+00 – 110+00) retreated 2 to 52 feet per year between October 1999 and April 2007. By contrast, the 3,000 foot segment on the south end of Hutaff Island advanced 15 feet/year between October 1999 and April 2005 (Table 6-3). Between April 2005 and April 2007, a large erosion loss occurred on southern Hutaff Island due to Hurricane Ophelia (October 2005) and the formation of a swash channel into Rich Inlet. Nevertheless, over the past 8 years as whole, the north end Figure Eight Island has experienced more erosion than the south end of Hutaff Island.

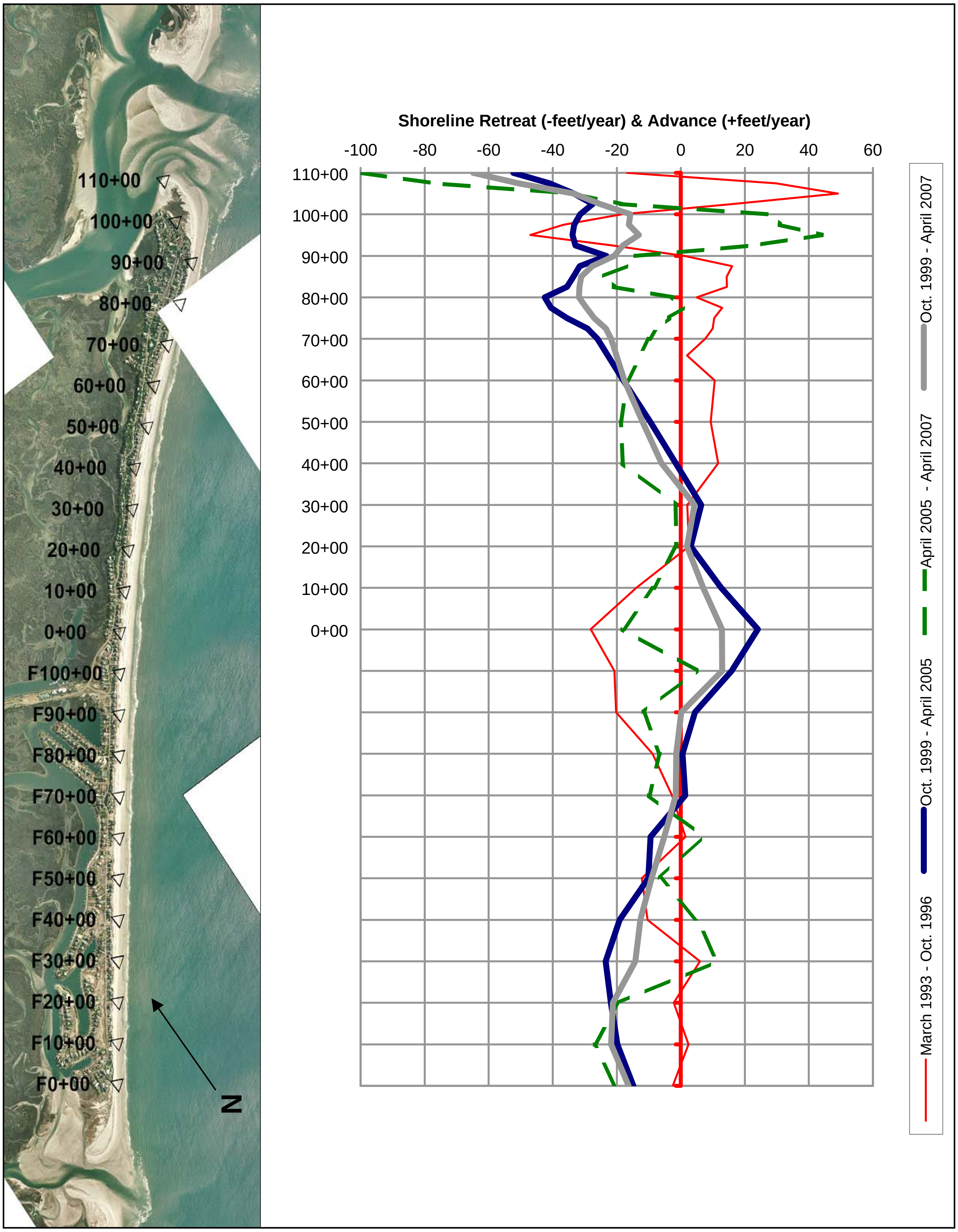



**FIGURE 6-2: Ocean Shoreline Changes, Figure Eight Island, NC.**

TABLE 6-1

OCEAN SHORELINE CHANGES
(adjusted for beach fills)
FIGURE EIGHT ISLAND, NC

| Profile Line | Beach Length (feet) | Shoreline Retreat (-feet/year) & Advance (+feet/year) | | | | |
|---|---|---|---|---|---|---|
| | | Mar 1993 to Oct 1996 | Oct 1999 to Apr 2005 | Apr 2005 to Apr 2007 | Oct 1999 to Apr 2007 | 1999-2007 Worst Case |
| F0+00 | 500 | -2 | -14.8 | -20.5 | -16.3 | -20.5 |
| F10+00 | 1,000 | 2 | -19.8 | -27.0 | -21.7 | -27.0 |
| F20+00 | 1,000 | -2 | -21.9 | -19.4 | -21.2 | -21.9 |
| F30+00 | 1,000 | 6 | -23.5 | 11.3 | -14.2 | -23.5 |
| F40+00 | 1,000 | -10 | -19.1 | 5.1 | -12.7 | -19.1 |
| F50+00 | 1,000 | -12 | -10.2 | -6.4 | -9.2 | -10.2 |
| F60+00 | 1,000 | 1 | -9.5 | 6.7 | -5.1 | -9.5 |
| F70+00 | 1,000 | -3 | 1.4 | -9.8 | -1.6 | -9.8 |
| F80+00 | 1,000 | -9 | 0.5 | -6.6 | -1.4 | -6.6 |
| F90+00 | 1,000 | -20 | 4.4 | -11.6 | 0.2 | -11.6 |
| F100+00 | 1,000 | -21 | 15.9 | 4.9 | 12.9 | 4.9 |
| 0+00 | 1,000 | -28 | 24.1 | -18.1 | 12.8 | -18.1 |
| 10+00 | 1,000 | -14 | 12.6 | -8.5 | 7.0 | -8.5 |
| 20+00 | 1,000 | 3 | 3.1 | -1.4 | 1.9 | -1.4 |
| 30+00 | 1,000 | 2 | 6.4 | -1.7 | 4.2 | -1.7 |
| 40+00 | 750 | 12 | -1.6 | -18.1 | -6.0 | -18.1 |
| 45+00 | 500 | 10 | -5.5 | -18.4 | -9.0 | -18.4 |
| 50+00 | 750 | 9 | -9.5 | -18.7 | -12.0 | -18.7 |
| 60+00 | 800 | 11 | -17.9 | -16.7 | -17.6 | -17.9 |
| 66+00 | 500 | 2 | -22.8 | -12.6 | -20.1 | -22.8 |
| 70+00 | 325 | 8 | -26.0 | -9.9 | -21.7 | -26.0 |
| 72+50 | 250 | 10 | -29.2 | -7.4 | -23.4 | -29.2 |
| 75+00 | 250 | 10 | -35.5 | -3.6 | -27.0 | -35.5 |
| 77+50 | 250 | 13 | -40.5 | 0.9 | -29.5 | -40.5 |
| 80+00 | 250 | 5 | -42.5 | -2.5 | -31.8 | -42.5 |
| 82+50 | 250 | 14 | -35.5 | -20.9 | -31.6 | -35.5 |
| 85+00 | 250 | 14 | -33.5 | -24.5 | -31.1 | -33.5 |
| 87+50 | 250 | 16 | -31.5 | -17.0 | -27.7 | -31.5 |
| 90+00 | 250 | 1 | -23.3 | -14.1 | -20.8 | -23.3 |
| 92+50 | 250 | -21 | -32.9 | 22.6 | -18.1 | -32.9 |
| 95+00 | 250 | -47 | -33.9 | 44.0 | -13.1 | -33.9 |
| 97+50 | 250 | -37 | -33.3 | 30.9 | -16.2 | -33.3 |
| 100+00 | 250 | -18 | -31.4 | 27.4 | -15.8 | -31.4 |
| 102+50 | 250 | 16 | -27.5 | -18.6 | -25.2 | -27.5 |
| 105+00 | 250 | 49 | -33.4 | -33.8 | -33.5 | -33.8 |
| 107+50 | 250 | 30 | -41.0 | -77.3 | -50.7 | -77.3 |
| 110+00 | 125 | -17 | -52.3 | -99.6 | -64.9 | -99.6 |
| F0+00 to F90+00 | 9,000 | -4 | -11.9 | -6.9 | -10.6 | -15.9 |
| F90+00 to 45+00 | 6,500 | -9 | 9.5 | -7.5 | 5.0 | -7.5 |
| 45+00 to 66+00 | 2,100 | 9 | -14.1 | -17.0 | -14.9 | -18.9 |
| 66+00 to 105+00 | 3,900 | 1 | -32.0 | -1.5 | -23.9 | -32.0 |

**TABLE 6-2**

**FIGURE EIGHT ISLAND BEACH FILLS**
**1993 - PRESENT**

| Project Date | Type of Project | Volume (c.y.) | Source | Profiles |
|---|---|---|---|---|
| Feb. 1993 | Beach nourishment | 274,000 | Nixon Channel | 60+00 to 105+00 |
| January 1997 | Storm recovery | Not avail. | Nixon Channel | 15+00 to 105+00 |
| March 1998 | Channel dredging | 450,000 | Banks Channel & Middle Sound | INN15+00 to 90+00 |
| March 1999 | Beach nourishment | 785,000 | Banks Channel | INN15+00 to 87+50 |
| March 2001 | Beach nourishment | 350,000 | Nixon Channel | 0+00 to 90+00 |
| Jan.-Feb. 2002 | Mason Inlet relocation | 390,000 | Mason Inlet | F0+00 to F100+00 |
| March 2003 | Channel dredging | 50,000 | Banks Channel & AIWW | INN10+00 to F14+00 |
| March 2003 | Sandbag placement* | 30,000 | Banks Channel & AIWW | 80+00 to 97+50 |
| Spring 2005 | Channel dredging | 183,000 | Mason Inlet | F12+00 to F57+00 |
| November 2005 | Beach nourishment | 261,235 | Nixon Channel | 30+00 to 95+00 |
| April 2006 | Beach nourishment | 148,969 | Mason Creek & AIWW | F-4+00 to F24+00 |
| Spring 2006 | Beach nourishment | 179,175 | Banks Channel | F24+00 to F80+00 |
| Spring 2009 | Channel Dredging | 295,000 | Nixon Channel | 67+00 to 95+00 |
| Spring 2009 | Beach Nourishment | 176,000 | Mason Inlet | F-2+00 to F100+00 |
| Jan-Mar 2011 | Channel Dredging | 275,000 | Nixon Channel | 0+00 to 95+00 |

Sources: All projects prior to 2005 - Cleary & Jackson (2004), Chapter 5.
Spring 2005 channel dredging - Gahagan & Bryant (2005).
November 2005 and subsequent projects - Gahagan & Bryant (2006).
* The 30,000 c.y. was placed outside the active beach profile and not incorporated in the shoreline retreat rates.

**TABLE 6-3**

**OCEAN SHORELINE CHANGES**
**HUTAFF ISLAND, NC**

| Profile Line | Beach Length (feet) | Shoreline Retreat (-feet/year) & Advance (+feet/year) Mar 1993 to Oct 1996 | Oct 1999 to Apr 2005 | Apr 2005 to Apr 2007 | Oct 1999 to Apr 2007 |
|---|---|---|---|---|---|
| 145+00 | 125 | -5 | -11.2 | -35.6 | -17.7 |
| 147+50 | 250 | 0 | -4.6 | -82.6 | -25.4 |
| 150+00 | 250 | -2 | 5.6 | -109.0 | -24.9 |
| 152+50 | 250 | -3 | 8.5 | -118.2 | -25.3 |
| 155+00 | 250 | -2 | 5.5 | -102.1 | -23.2 |
| 157+50 | 250 | -9 | 10.8 | -94.2 | -17.2 |
| 160+00 | 250 | -20 | 14.8 | -82.4 | -11.1 |
| 162+50 | 250 | -26 | 16.2 | -67.7 | -6.2 |
| 165+00 | 250 | -29 | 19.9 | -52.7 | 0.5 |
| 167+50 | 250 | -36 | 23.3 | -40.3 | 6.3 |
| 170+00 | 250 | -36 | 30.1 | -30.5 | 14.0 |
| 172+50 | 250 | -40 | 34.9 | -35.8 | 16.1 |
| 175+00 | 125 | -36 | 34.5 | -31.9 | 16.8 |
| 145+00 to 175+00 | 3,000 | -19 | 14.7 | -70.8 | -8.1 |

The erosional period on the north end of Figure Eight Island started in 1997. Since 1997, the main channel of Rich Inlet has moved towards its present location near Hutaff Island. However, in 1993, the main channel of the inlet was located closer to Figure Eight Island, as shown in Figure 5-4. Shoreline changes between 1993 and 1996 appear in Figure 6-2, Table 6-1, and Table 6-3. During this period, the northern half of Figure Eight Island (profiles 20+00 to 90+00 and 102+50 to 107+50) was accretional. The only erosion hotspot was located north of Inlet Hook Road (profiles 92+50 to 100+00). Conversely, the south end of Hutaff Island was erosional during this period. In general, a "comparison of the shoreline change data for Figure Eight Island and Hutaff Island for various periods since 1938 indicates that the updrift and downdrift barriers generally have opposing erosion/accretion trends. The major reversals in the accretion patterns and the onset of erosion are directly related to changes in the position of the ebb channel." (Cleary and Jackson, 2004, p. 146).

## 7.0 VOLUMETRIC CHANGE ANALYSIS

Volumetric changes along Figure Eight Island are based on the April 2005, April 2006, and April 2007 monitoring surveys by Gahagan & Bryant (2006, 2007). Available surveys prior to October 2004 were taken above wading depth (-4' NAVD) only, rendering them insufficient for a true volumetric change analysis.

Volume changes between April 2005 and April 2007 appear in Table 7-1 and Figure 7-1. Volume changes were computed using Beach Morphology Analysis Package Version 2.0 (BMAP, Sommerfeld, et al, 1994). The plotting routine within BMAP was utilized to evaluate the limits beyond which the apparent profile changes were dominated by survey error.

Between April 2005 and April 2007, Figure Eight Island gained 136,800 cubic yards (see Table 7-1, column 3). However, over 589,000 cubic yards of material was placed on the island (Table 6-2) between these dates. Without the beach fill, the island would have lost 452,900 cubic yards (see Table 7-1, column 5), equal to an average erosion rate of 10 c.y./year/foot. Most of the island was erosional between April 2005 and April 2007. Natural gains were limited to a few isolated areas near Bayberry Place (0+00), profiles 20+00 to 30+00, Surf Court (75+00), and Rich Inlet (105+00). The highest erosion rates occurred near Mason Inlet (INN15+00 to F20+00) and Inlet Hook Road (90+00). Moderate erosion occurred between profile 35+00 and Surf Court (70+00).

On the southern end of Hutaff Island (145+00 to 170+00), the beach lost 399,700 cubic yards. As noted earlier, this erosion was caused by Hurricane Ophelia (October 2005) and the formation of a swash channel into Rich Inlet. Based on a comparison of Tables 6-3 and 7-1, the 2005-2007 erosion patterns were not typical of the long term trend since 1999. Furthermore, they were considerably higher than the 1938-1998 erosion rates compiled by Cleary (2008).

## TABLE 7-1

## OCEANFRONT VOLUME CHANGES
## APRIL 2005 - APRIL 2007
## FIGURE EIGHT & HUTAFF ISLAND, NC

| Profile Line | Beach Length (feet) | April 2005 - April 2007 Volume Change (c.y.) | | | 2005-2007 Volume Change Rates (c.y./year) |
|---|---|---|---|---|---|
| | | Surveyed Changes | Beach Fills | Adjusted Changes | |
| INN15+00 | | | | | |
| | 100 | -5,600 | 0 | -5,600 | -2,800 |
| F-4+00 | | | | | |
| | 400 | -16,400 | 9,300 | -25,700 | -12,850 |
| F0+00 | | | | | |
| | 100 | -2,700 | 5,300 | -8,000 | -4,000 |
| F1+00 | | | | | |
| | 400 | -8,000 | 23,400 | -31,400 | -15,700 |
| F5+00 | | | | | |
| | 500 | -3,200 | 29,200 | -32,400 | -16,200 |
| F10+00 | | | | | |
| | 200 | 400 | 11,700 | -11,300 | -5,650 |
| F12+00 | | | | | |
| | 200 | 900 | 11,700 | -10,800 | -5,400 |
| F14+00 | | | | | |
| | 600 | 5,400 | 35,100 | -29,700 | -14,850 |
| F20+00 | | | | | |
| | 400 | 4,800 | 23,400 | -18,600 | -9,300 |
| F24+00 | | | | | |
| | 500 | 5,700 | 22,000 | -16,300 | -8,150 |
| F29+00 | | | | | |
| | 100 | 1,100 | 2,900 | -1,800 | -900 |
| F30+00 | | | | | |
| | 1,000 | 12,900 | 29,400 | -16,500 | -8,250 |
| F40+00 | | | | | |
| | 1,000 | 18,400 | 29,400 | -11,000 | -5,500 |
| F50+00 | | | | | |
| | 200 | 3,900 | 5,900 | -2,000 | -1,000 |
| F57+00 | | | | | |
| | 800 | 6,800 | 23,500 | -16,700 | -8,350 |
| F60+00 | | | | | |
| | 1,000 | 1,100 | 29,400 | -28,300 | -14,150 |
| F70+00 | | | | | |
| | 1,000 | 6,000 | 29,400 | -23,400 | -11,700 |
| F80+00 | | | | | |
| | 500 | 2,200 | 7,300 | -5,100 | -2,550 |
| F85+00 | | | | | |
| | 500 | -2,700 | 0 | -2,700 | -1,350 |
| F90+00 | | | | | |

## TABLE 7-1

### OCEANFRONT VOLUME CHANGES
### APRIL 2005 - APRIL 2007
### FIGURE EIGHT & HUTAFF ISLAND, NC

| Profile Line | Beach Length (feet) | April 2005 - April 2007 Volume Change (c.y.) | | | 2005-2007 Volume Change Rates (c.y./year) |
|---|---|---|---|---|---|
| | | Surveyed Changes | Beach Fills | Adjusted Changes | |
| | 500 | -3,900 | 0 | -3,900 | -1,950 |
| F95+00 | | | | | |
| | 500 | -1,300 | 0 | -1,300 | -650 |
| F100+00 | | | | | |
| | 1,000 | 5,400 | 0 | 5,400 | 2,700 |
| 0+00 | | | | | |
| | 500 | 500 | 0 | 500 | 250 |
| 5+00 | | | | | |
| | 500 | -9,100 | 0 | -9,100 | -4,550 |
| 10+00 | | | | | |
| | 1,000 | -13,000 | 0 | -13,000 | -6,500 |
| 20+00 | | | | | |
| | 1,000 | 3,500 | 0 | 3,500 | 1,750 |
| 30+00 | | | | | |
| | 500 | 4,200 | 10,900 | -6,700 | -3,350 |
| 35+00 | | | | | |
| | 500 | 7,400 | 21,800 | -14,400 | -7,200 |
| 40+00 | | | | | |
| | 500 | 9,000 | 21,800 | -12,800 | -6,400 |
| 45+00 | | | | | |
| | 500 | 9,000 | 21,800 | -12,800 | -6,400 |
| 50+00 | | | | | |
| | 1,000 | 15,100 | 43,500 | -28,400 | -14,200 |
| 60+00 | | | | | |
| | 600 | 10,300 | 26,100 | -15,800 | -7,900 |
| 66+00 | | | | | |

## TABLE 7-1

### OCEANFRONT VOLUME CHANGES
### APRIL 2005 - APRIL 2007
### FIGURE EIGHT & HUTAFF ISLAND, NC

| Profile Line | Beach Length (feet) | April 2005 - April 2007 Volume Change (c.y.) | | | 2005-2007 Volume Change Rates (c.y./year) |
|---|---|---|---|---|---|
| | | Surveyed Changes | Beach Fills | Adjusted Changes | |
| | 400 | 10,100 | 17,400 | -7,300 | -3,650 |
| 70+00 | | | | | |
| | 250 | 8,800 | 10,900 | -2,100 | -1,050 |
| 72+50 | | | | | |
| | 250 | 12,300 | 10,900 | 1,400 | 700 |
| 75+00 | | | | | |
| | 250 | 13,200 | 10,900 | 2,300 | 1,150 |
| 77+50 | | | | | |
| | 250 | 11,400 | 10,900 | 500 | 250 |
| 80+00 | | | | | |
| | 250 | 8,600 | 10,900 | -2,300 | -1,150 |
| 82+50 | | | | | |
| | 250 | 4,900 | 10,900 | -6,000 | -3,000 |
| 85+00 | | | | | |
| | 250 | 800 | 10,900 | -10,100 | -5,050 |
| 87+50 | | | | | |
| | 250 | -3,600 | 10,900 | -14,500 | -7,250 |
| 90+00 | | | | | |
| | 250 | -7,300 | 8,200 | -15,500 | -7,750 |
| 92+50 | | | | | |
| | 250 | -10,400 | 2,700 | -13,100 | -6,550 |
| 95+00 | | | | | |
| | 250 | -8,000 | 0 | -8,000 | -4,000 |
| 97+50 | | | | | |
| | 250 | -200 | 0 | -200 | -100 |
| 100+00 | | | | | |
| | 250 | 6,000 | 0 | 6,000 | 3,000 |
| 102+50 | | | | | |
| | 250 | 10,600 | 0 | 10,600 | 5,300 |
| 105+00 | | | | | |
| | 250 | 9,300 | 0 | 9,300 | 4,650 |
| 107+50 | | | | | |
| | 250 | 2,200 | 0 | 2,200 | 1,100 |
| 110+00 | | | | | |

**TABLE 7-1**

**OCEANFRONT VOLUME CHANGES**
**APRIL 2005 - APRIL 2007**
**FIGURE EIGHT & HUTAFF ISLAND, NC**

| Profile Line | Beach Length (feet) | April 2005 - April 2007 Volume Change (c.y.) | | | 2005-2007 Volume Change Rates (c.y./year) |
|---|---|---|---|---|---|
| | | Surveyed Changes | Beach Fills | Adjusted Changes | |
| INN15+00 to F0+00 | 500 | -22,000 | 9,300 | -31,300 | -15,650 |
| F0+00 to F90+00 | 9,000 | 53,000 | 319,000 | -266,000 | -133,000 |
| F90+00 to 45+00 | 6,500 | 2,700 | 54,500 | -51,800 | -25,900 |
| 45+00 to 66+00 | 2,100 | 34,400 | 91,400 | -57,000 | -28,500 |
| 66+00 to 105+00 | 3,900 | 57,200 | 115,500 | -58,300 | -29,150 |
| 105+00 to 110+00 | 500 | 11,500 | 0 | 11,500 | 5,750 |
| FIGURE 8 ISLAND INN15+00 to 110+00 | 22,500 | 136,800 | 589,700 | -452,900 | -226,450 |

## TABLE 7-1

## OCEANFRONT VOLUME CHANGES
## APRIL 2005 - APRIL 2007
## FIGURE EIGHT & HUTAFF ISLAND, NC

| Profile Line | Beach Length (feet) | April 2005 - April 2007 Volume Change (c.y.) | | | 2005-2007 Volume Change Rates (c.y./year) |
|---|---|---|---|---|---|
| | | Surveyed Changes | Beach Fills | Adjusted Changes | |
| 145+00 | | | | | |
| | 250 | -26,800 | 0 | -26,800 | -13,400 |
| 147+50 | | | | | |
| | 250 | -30,500 | 0 | -30,500 | -15,250 |
| 150+00 | | | | | |
| | 250 | -34,100 | 0 | -34,100 | -17,050 |
| 152+50 | | | | | |
| | 250 | -37,800 | 0 | -37,800 | -18,900 |
| 155+00 | | | | | |
| | 250 | -39,500 | 0 | -39,500 | -19,750 |
| 157+50 | | | | | |
| | 250 | -39,100 | 0 | -39,100 | -19,550 |
| 160+00 | | | | | |
| | 250 | -38,700 | 0 | -38,700 | -19,350 |
| 162+50 | | | | | |
| | 250 | -38,400 | 0 | -38,400 | -19,200 |
| 165+00 | | | | | |
| | 250 | -35,800 | 0 | -35,800 | -17,900 |
| 167+50 | | | | | |
| | 250 | -31,100 | 0 | -31,100 | -15,550 |
| 170+00 | | | | | |
| | 250 | -26,300 | 0 | -26,300 | -13,150 |
| 172+50 | | | | | |
| | 250 | -21,600 | 0 | -21,600 | -10,800 |
| 175+00 | | | | | |
| SOUTHERN HUTAFF IS. 145+00 to 175+00 | 3,000 | -399,700 | 0 | -399,700 | -199,850 |

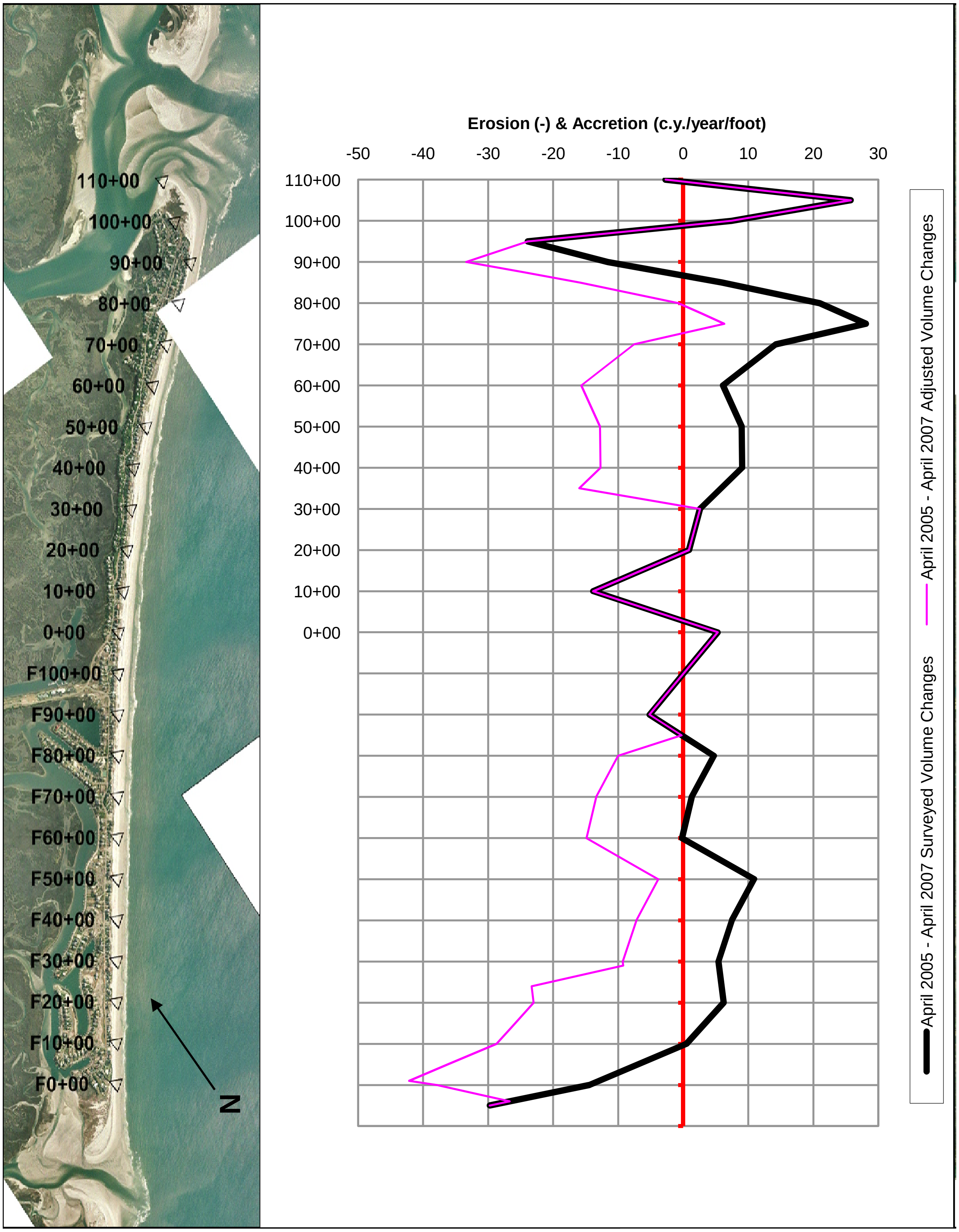



**FIGURE 7-1: April 2005 - April 2007 Volumetric Changes, Figure Eight Island, NC.**

## 8.0 LITTORAL BUDGET

### 8.1 April 2005 – April 2007 Sediment Budget

Based on the volumetric changes in the previous section, two sediment budgets were developed to map the movement of material along Figure Eight Island and Rich Inlet: April 2005-April 2007 and October 1999-April 2007. For the shorter time period, changes on the oceanfront beaches were based on the erosion rates appearing in Figure 7-1 and Table 7-1. These changes were dominated by Hurricane Ophelia (September 2005) and beach nourishment operations on the northern and southern ends of the island. Volumetric changes near Rich Inlet were based on the April 2005, April 2006, and April 2007 surveys (Figures 8-1 to 8-3). To map the movement of material in Rich Inlet, the inlet and ebb shoal complex was divided into the following cells, which appear in Figure Eight-1:

- Outer Ebb Shoal.
- Existing Channel.
- Southwest Flood Channels.
- Inlet Interior.

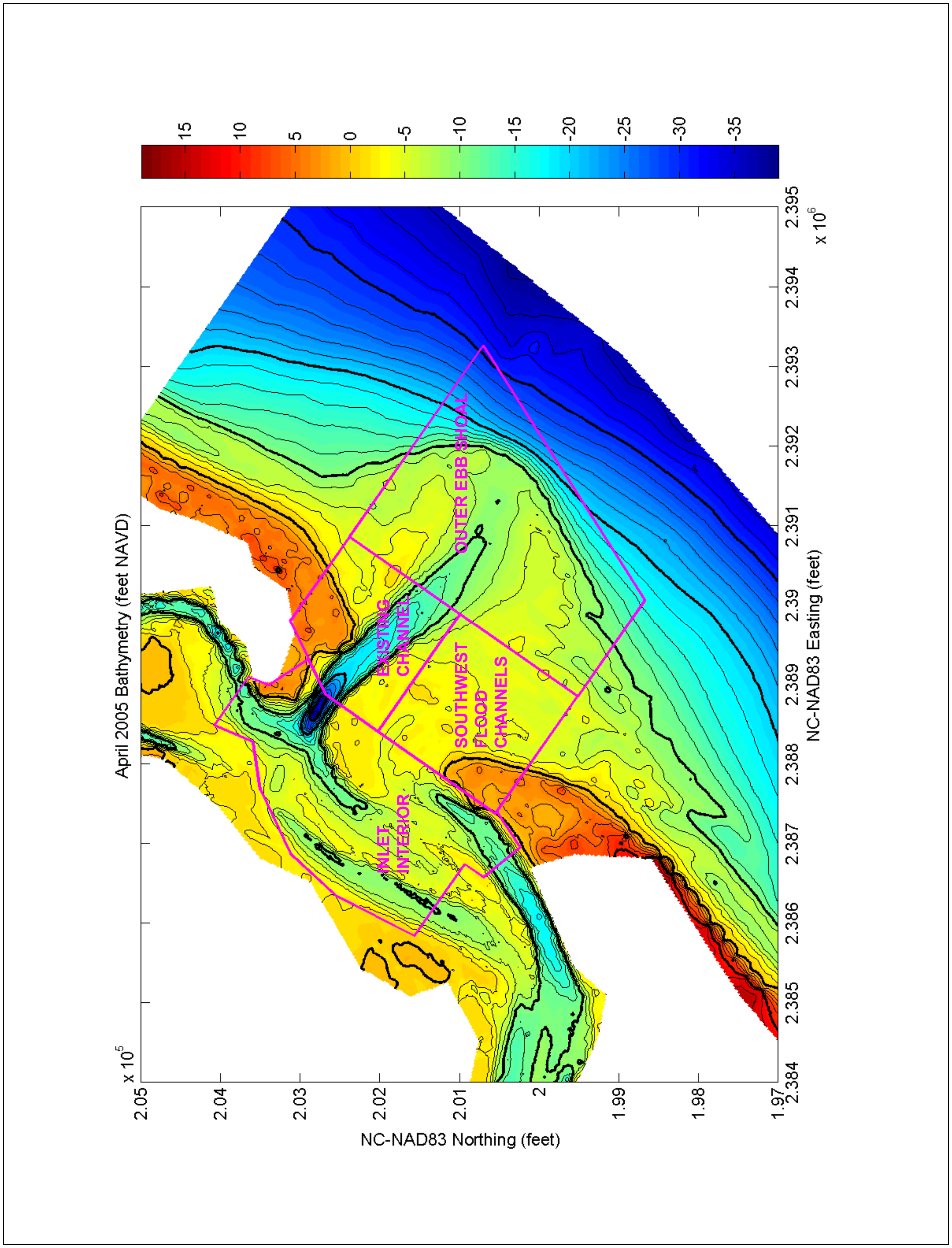



**FIGURE 8-1: April 2005 Bathymetry, Figure Eight Island and Rich Inlet, NC.**

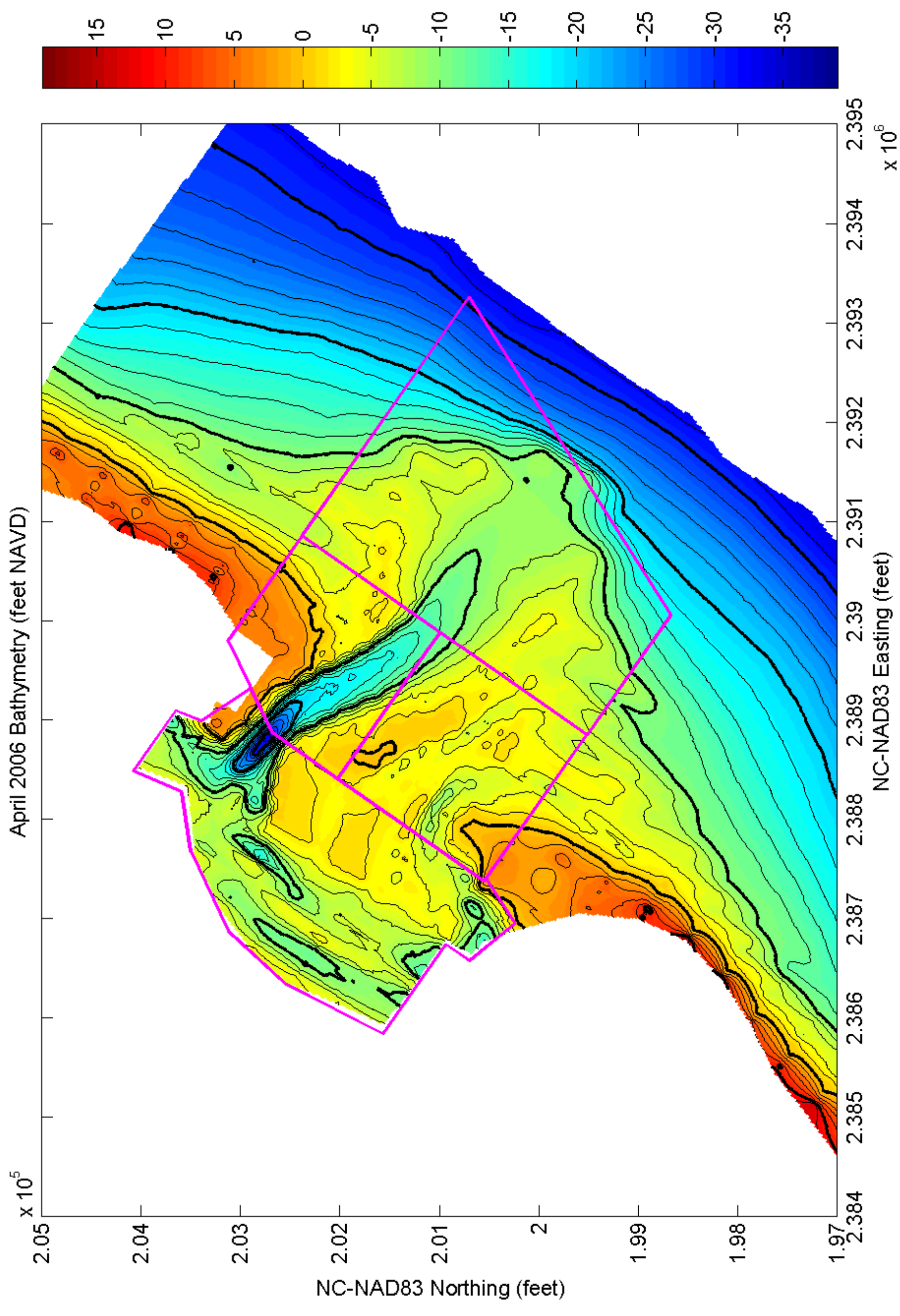



**FIGURE 8-2: April 2006 Bathymetry, Figure Eight Island and Rich Inlet, NC.**

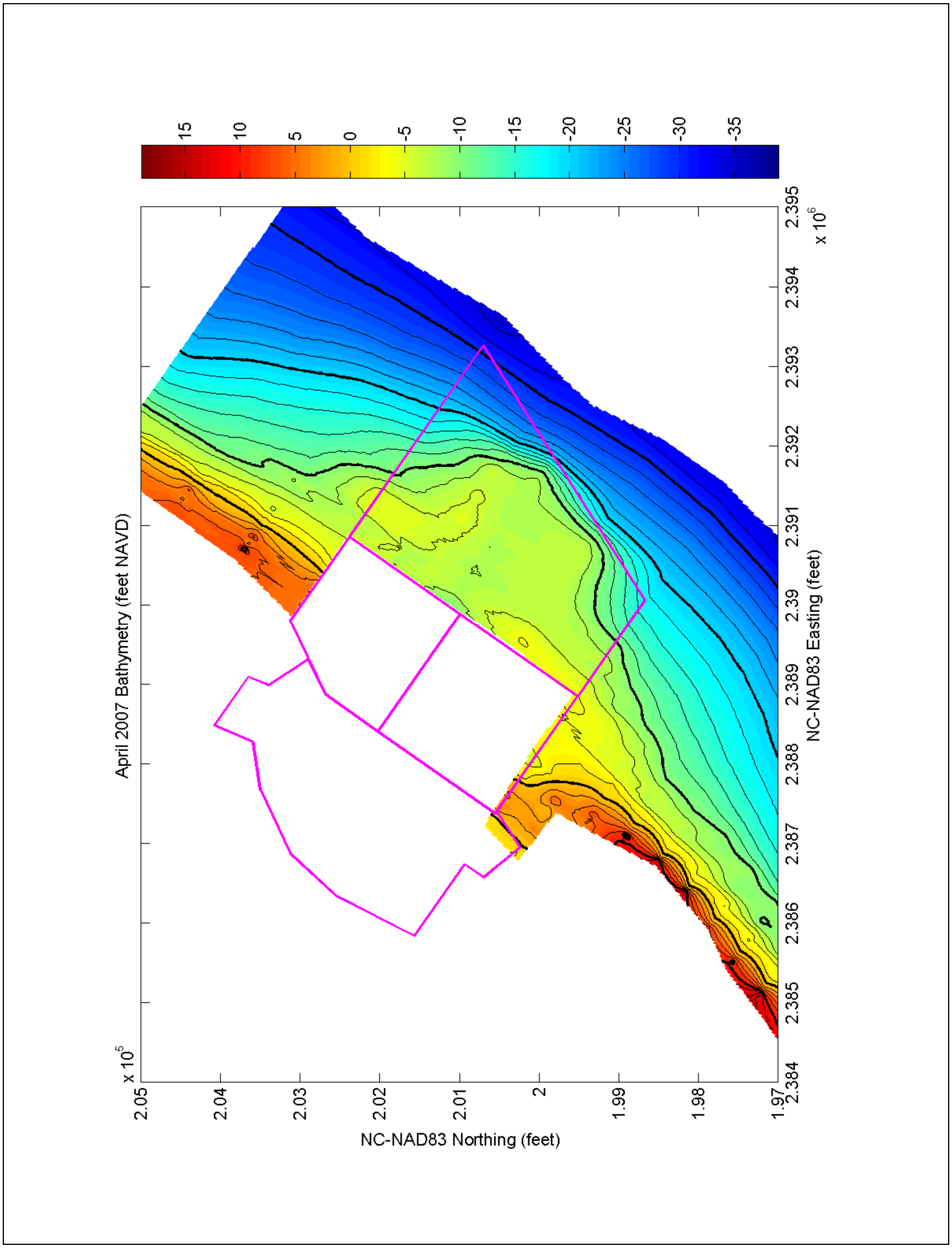



**FIGURE 8-3: April 2007 Bathymetry, Figure Eight Island and Rich Inlet, NC.**

The locations of these cells were based on the morphology of the inlet and the limits of the 2005, 2006, and 2007 surveys. Changes within the Outer Ebb Shoal were based on the April 2005 and April 2007 surveys. In the other inlet cells, the April 2007 survey did not provide sufficient coverage or spacing to realistically depict the bathymetry. Accordingly, changes in the other 3 inlet cells were based on the April 2005 and April 2006 surveys.

Sediment budget cells along the beach were based on the proposed beach fill layouts, discussed later in this report. South of the beach disposal area, additional cells were delineated based on the available survey data. Oceanfront sediment budget cells are listed in Table 8-1:

**TABLE 8-1**

**OCEANFRONT SEDIMENT BUDGET CELLS**
**FIGURE EIGHT ISLAND, NC**

| Profile Lines | Beach Length (feet) | Description |
|---|---|---|
| INN10+00 to INN15+00 | 500 | Undeveloped beach near Mason Inlet (1999-2007 only) |
| INN15+00 to F0+00 | 500 | 188 Beach Road S to 184 Beach Road S (wide lots) |
| F0+00 to F90+00 | 9,000 | 184 Beach Road S to 8 Beach Road S |
| F90+00 to 45+00 | 6,500 | 8 Beach Road S to 292 Beach Road N |
| 45+00 to 66+00 | 2,100 | 292 Beach Road N to Surf Court |
| 66+00 to 105+00 | 3,900 | Surf Court to Inlet Hook Roads (Rich Inlet erosion hotspot) |
| 105+00 to 110+00 | 500 | Undeveloped beach near Rich Inlet |
| 145+00 to 175+00 | 3,000 | Southern Hutaff Island |

Transport rates between the various cells in Rich Inlet were generally based on preliminary Delft3D model results between April 2005 and April 2007. Transport rates on Hutaff Island were then determined based on the observed volume changes (Table 7-1) and the amount of material entering Rich Inlet. Transport rates on Figure Eight Island were determined based on the volumetric changes in Figure 7-1. Between 2005 and 2007, a high erosion area was centered near profile 95+00 (Inlet Hook Road). Accreting areas were located on either side of this erosion hotspot, suggesting the presence of a nodal point, or the transport of material away from profile 95+00 in either direction. Based on the other observed volume changes and fill quantities on the island, transport rates along the remainder of the island were estimated.

The April 2005 – April 2007 sediment budget appears in Figure 8-4. Over the 2 year period, the south end of Hutaff Island lost 199,850 c.y./year. Most of this material went into the Rich Inlet complex, which gained 182,000 c.y./year. Within the inlet complex, the Existing Channel was the primary pathway for offshore transport of sediment, and the Southwest Flood Channels were the primary pathway for the inland transport of sediment.

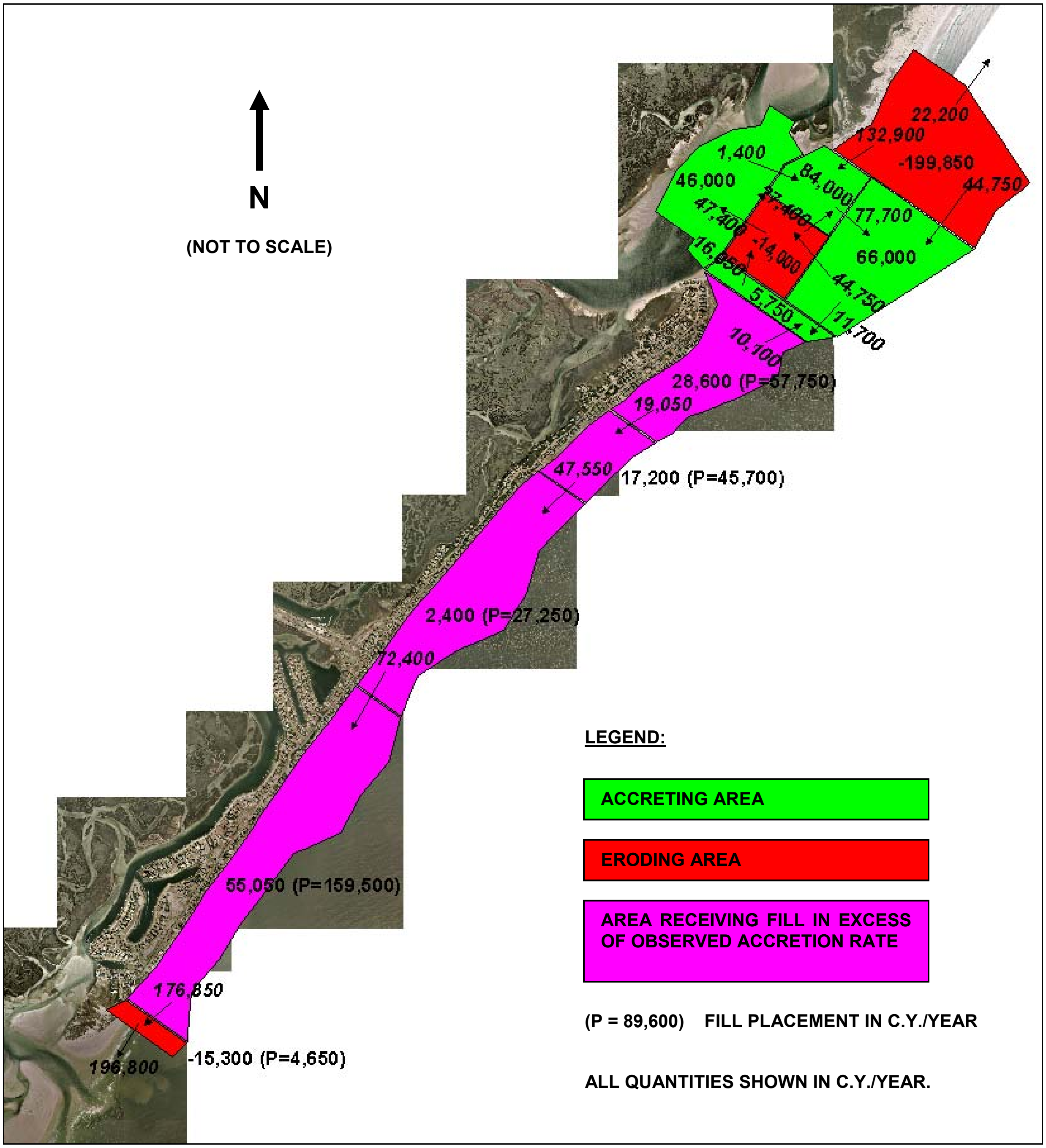



**FIGURE 8-4: Figure Eight Island April 2005 – April 2007 Sediment Budget.**

Along Figure Eight Island, the net transport was towards the south. Between profile 95+00 (Inlet Hook Road) and F-4+00 (south end of Beach Road), there was a consistent increase in the sediment transport rate from 0 to 196,800 c.y./year.

## 8.2 October 1999 – April 2007 Sediment Budget

For the longer time period, changes on the oceanfront beaches were based on the 1999-2007 shoreline changes. A detailed bathymetric survey of Rich Inlet prior to 2004 was not available. Accordingly, the inlet and ebb shoal was schematized as a single cell, with volumetric changes estimated based on sediment transport along the adjacent beaches.

The October 1999 – April 2007 sediment budget appears in Figure 8-5. During the 7½ year period, the highest rates of retreat occurred near profiles 80+00 (Comber Road) and 110+00 (Rich Inlet) (Figure 6-2). Accordingly, profile 80+00 (Comber Road) was assumed to be a nodal point, with transport of material away from the area in either direction. Given the observed shoreline changes and beach fills (Table 6-2), the estimated sediment transport was 63,200 c.y./year to northeast at profile 105+00 and 37,100 c.y./year to the southwest at profile 66+00 (Surf Court). Based on the other observed changes and fill quantities on the island, sediment transport rates along the remainder of the island were estimated.

South of profile 66+00 (Surf Court), the net sediment transport was from northeast to southwest. Between Backfin Point (F80+00) and 268 Beach Road North (35+00), there was an accreting area characterized by a decreasing rate of sediment transport. However, the direction of sediment transport was towards the southwest along this reach. South of Backfin Point (F80+00), the beaches were erosional, with an increasing rate of sediment transport towards the southwest.

The net sediment transport near Mason Inlet (INN10+00) was less than the 2005-2007 sediment budget. However, it was consistent with the migration pattern of Mason Inlet prior to 2002, which moved 2,200 feet southwest between 1985 and 2002 (Erickson, Kraus, and Carr, 2003), or approximately 129 feet/year. Based on the inlet migration rate, a +6 foot NAVD berm elevation, a -24 foot NAVD depth of closure, and a cross-shore width of 900 feet, the equivalent sediment transport would be 129,000 c.y./year. This value was close to the sediment transport rate of 142,900 c.y./year in Figure 8-5.

On the south end of Hutaff Island, the net transport rates between 1999 and 2007 were low. Transport rates at profile 175+00 were based on preliminary Delft3D model results for the 5-year, without-project scenario. Transport rates into Rich Inlet were then determined based on the observed shoreline changes between 1999 and 2007. Given the transport rates on either side of Rich Inlet, the inlet and ebb shoal gained approximately 120,600 c.y./year between October 1999 and April 2007. While the gain was 2/3 the combined value shown in Figure 8-4, it was based on erosion rates that were more representative of the study area than the 2005-2007 rates.

## 8.3 Summary

Based on the two sediment budgets, Rich Inlet is a sediment sink that gains 100,000 to 200,000 c.y./year. The source of this material alternates between the adjacent beaches on Figure Eight Island and the adjacent beaches on Hutaff Island. The recent source is primarily Hutaff Island.

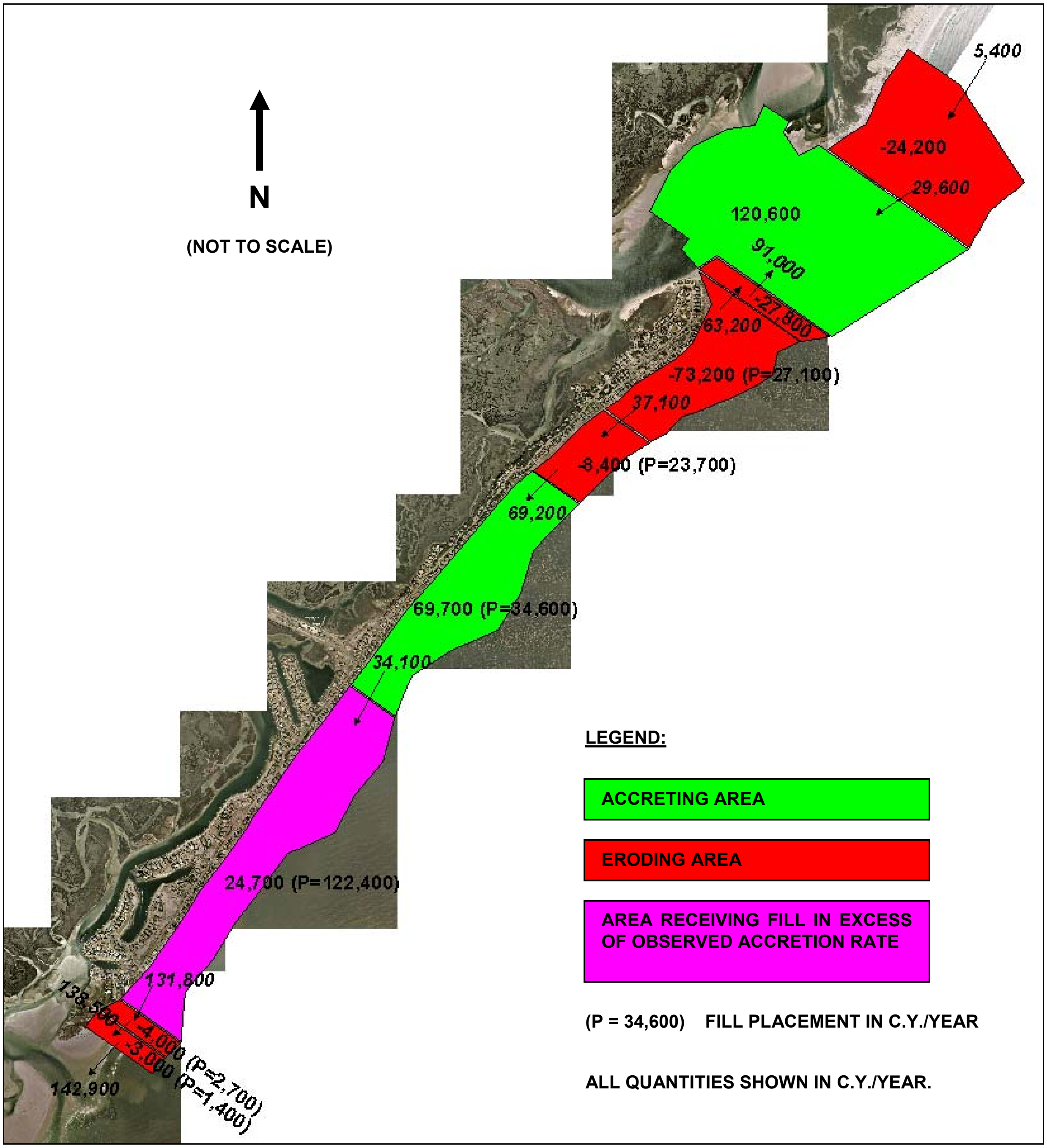



**FIGURE 8-5: Figure Eight Island October 1999 – April 2007 Sediment Budget.**

Near the northern end of Figure Eight Island, there is a nodal point, at which eroding sediments spread towards both the northeast and the southwest. This nodal point has shifted towards the northeast since 1999, but currently lies near Inlet Hook Road (profile 95+00). Along the rest of Figure Eight Island, the predominant sediment transport is towards the southwest. Sediment transport rates just north of Mason Inlet (profile F-4+00) vary from 142,900 to 196,800 c.y./year. Given the general erosion patterns around Rich Inlet, the northeasterly sediment transport on Topsail Island (USACE, 2006, p. 31), and the southwesterly transport near Mason Inlet, the area surrounding Rich Inlet functions as a nodal point on regional basis.

## 9.0 PROJECT DESIGN

The main text of the Environmental Impact Statement presents the following alternatives to address chronic erosion on Figure Eight Island:

1. No Action.

2. Abandon/Retreat.

3. Rich Inlet Management and Beach Fill.

4. Beach Fill without Management of Rich Inlet.

5. Terminal Groin with:
    a. Beach Fill from Nixon Channel & New Connector.
    b. Beach Fill from Other Sources.

Alternative 1 assumes that the present strategies to manage the island's shoreline in Table 6-2 will continue into the future. Alternative 2 assumes that there will be no more beach fill, dune maintenance, inlet maintenance, or sand bag placement operations. Accordingly, this alternative is the true "Without-Project" scenario. Alternative 3 implements the recommended modification of the Rich Inlet ocean bar channel proposed by Cleary (Sub-Appendix A), which is further detailed in this section. Dredged material from the inlet modification would be strategically placed along the north half of the island to mitigate for the erosion occurring since the late 1990s. Alternative 4 has a beach fill layout identical to Alternative 3 with the fill material to be taken from an undisclosed offshore source as well as from maintenance of the existing navigation channel in Nixon Channel. In this regard, potential offshore sand sources have been identified by Cleary (Cleary, 2000) but have not been investigated in sufficient detail to allow for the full development of this alternative. Alternative 5 utilizes a terminal groin to create an accretion fillet on the extreme north end of Figure Eight Island and reduce erosion rates from the beach fill placed north of Bridge Road to Rich Inlet. This alternative includes beach fill material from maintenance of the existing navigation channel in Nixon Channel and a new channel connector between Nixon Channel and the inlet gorge (Alternative 5A), material from sources other than the Rich Inlet complex (Alternative 5B), and fill from maintenance of the existing navigation channel in Nixon Channel (Alternative 5C).

### 9.1 Alternative 3 – Rich Inlet Management and Beach Fill

#### 9.1.1 Channel Location

Many of the erosion problems on the northern half of Figure Eight Island are to due changes in the location and alignment of the ebb shoal and main entrance channel at Rich Inlet. Based on thorough analysis of inlet characteristics between 1938 and 2001, reported by Cleary and Jackson (2004) and an update of that analysis that includes changes between 2001 and 2007 prepared by Dr. Cleary for this report, which is provided in Sub-Appendix A, a recommended optimum channel location was developed which is shown in Figure 9-1. This channel is located in the middle of the inlet approximately 2600 feet northeast of N. Beach Road (536 block).

Based on the trends observed by Cleary and Jackson (2004) and more recently by Cleary (Sub-Appendix A), relocating the channel will also shift the ebb shoal, providing a buffer against wave-driven erosion. As noted in Section 6, the south end of Hutaff Island is eroding partly due to the formation of a swash channel. The formation of the swash channel has partially depleted the ebb shoal on the north side of Rich Inlet. On the other hand, when the north side of the ebb shoal is fully intact, the south end of Hutaff Island accretes. Given these observations, relocating the channel as shown is Figure 9-1 is a possible means of controlling erosion on the north end of Figure Eight Island without using structures.

### 9.1.2 Closure Dike

To ensure a successful relocation of the channel, it is necessary to close the existing channel. This task will be accomplished by building a closure dike out of the material dredged from the relocated channel. The Delft3D modeling results in a later section of this report show that without a dike, the existing channel will continue to carry the flow through Rich Inlet. The modeling results also show that the dike must be of sufficient size to remain in place for more than a few months. The closure dike at Rich Inlet will have the following dimensions:

Crest Elevation = +6 feet NAVD
Crest Width = 450 feet
Side Slopes ~ 1 vertical on 20 horizontal

### 9.1.3 Entrance Channel Dimensions

To establish dimensions of the ebb/entrance channel, an inlet stability analysis has been conducted. The inlet stability analysis utilizes two curves (Figure 9-2): the O'Brien curve and the Escoffier curve. The O'Brien curve is an empirical relationship between tidal prism and the cross-sectional area at the throat of the inlet. The Escoffier curve is a theoretical relationship between the tidal current velocity and the cross-sectional area. Currents at the inlet throat were measured by Gahagan & Bryant Associates, Inc. in June 2005. The most recent survey of the inlet throat was taken by Gahagan & Bryant Associates, Inc. in April 2006. As shown in Figure 9-2, the observed flood currents and cross-sectional area fall on the Escoffier curve.

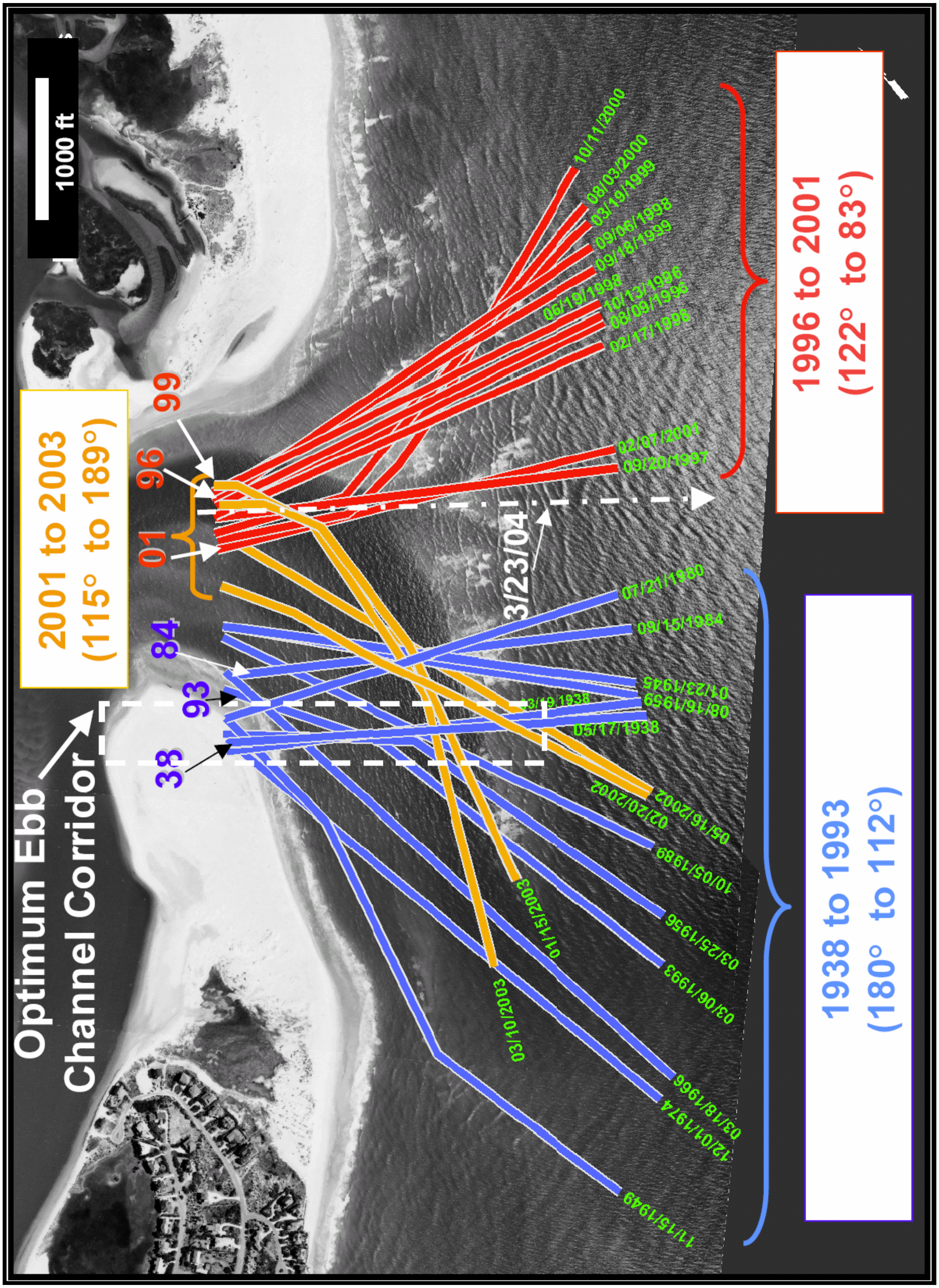



**FIGURE 9-1: Rich Inlet Optimum Channel Location (Cleary and Jackson, 2004).**

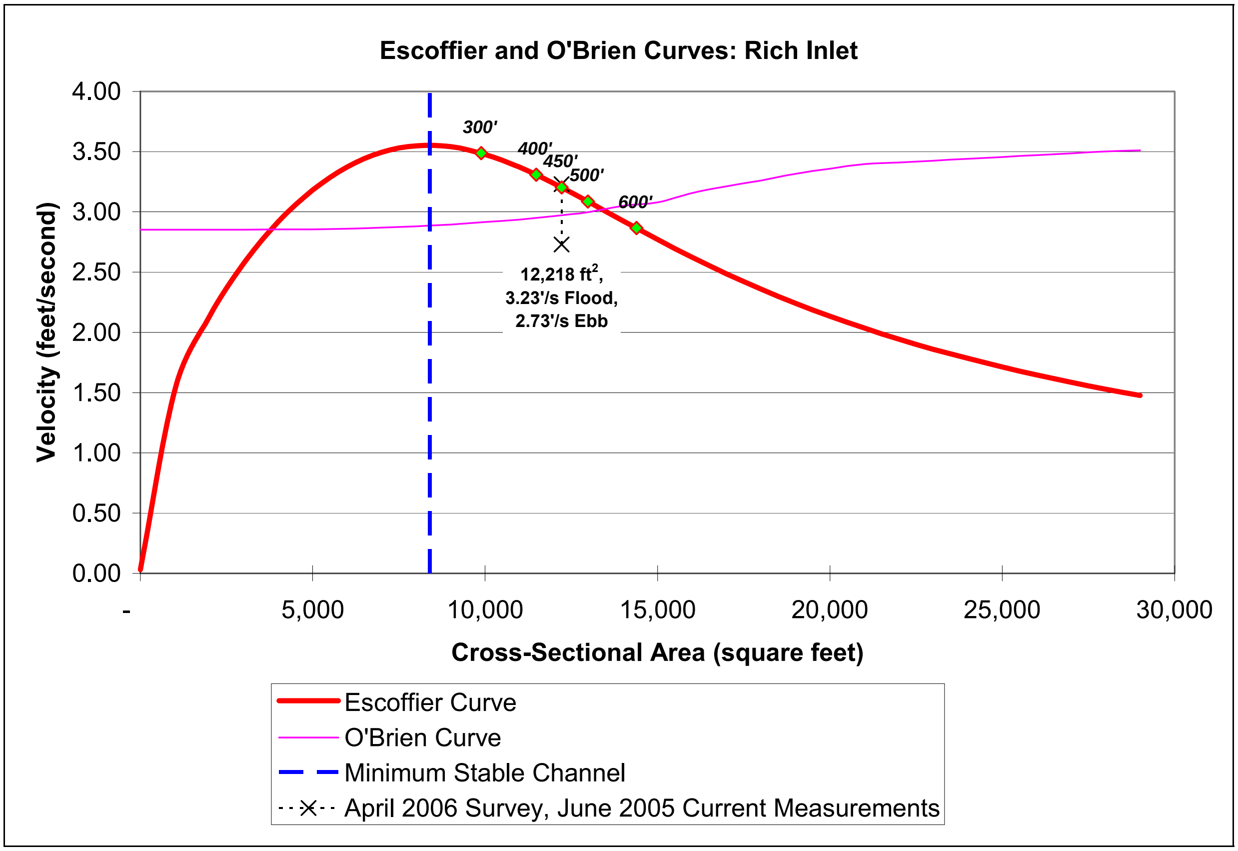



**FIGURE 9-2: Inlet Stability Curves for Rich with Bottom Widths Given a Design Depth of -19 feet NAVD and Side Slopes of 1V:5H.**

The O'Brien curve crosses the Escoffier curve at two points. The left point is the unstable equilibrium, which corresponds to a cross-sectional area of 3,800 square feet. Any deviation from that point immediately sets into action forces which tend to further increase or aggravate the deviation (Escoffier, 1940). If the deviation is a reduction in the cross-sectional area, the inlet closes. The right point is the stable equilibrium, which corresponds to a cross-sectional area of 13,400 square feet. Any deviation from that point immediately sets into action forces which tend to restore the channel to its initial condition (Escoffier, 1940). Between the two crossing points, the Escoffier curve peaks at a cross-sectional area of 8,400 square feet. This value represents the minimum cross-sectional area for the inlet to remain stable.

The initial designs and preliminary model simulations for Rich Inlet assumed a design depth of -17 feet NAVD. However, based on conversations with dredge contractors, a design depth of -19 feet NAVD was found to be easier and less expensive to construct. Thus, the design depth was modified to -19 feet NAVD, with side slopes of 1 vertical on 5 horizontal.

The closure dike will reduce the cross-sectional area by 8,600 square feet (Figure 9-3) which would reduce the cross-sectional area of the inlet to approximately 3,600 square feet. Based on the stability analysis presented above, this would result in an unstable inlet. For the inlet to remain stable, its cross-sectional area needs to be at least 8,400 square feet. This can be accomplished using a design cross-section with a bottom width of 300 feet. However, the 300 foot bottom width does not offer an appropriate safety factor. Furthermore, it does not restore the cross-section to present size. A bottom width of 500 to 600 feet achieves the stable equilibrium of 13,400 square feet. However, this size is not the most cost-effective, and creates a larger project footprint. A bottom width of 450 feet was selected and restores the cross-sectional to its present size. Natural forces can then be allowed to increase the cross-section.

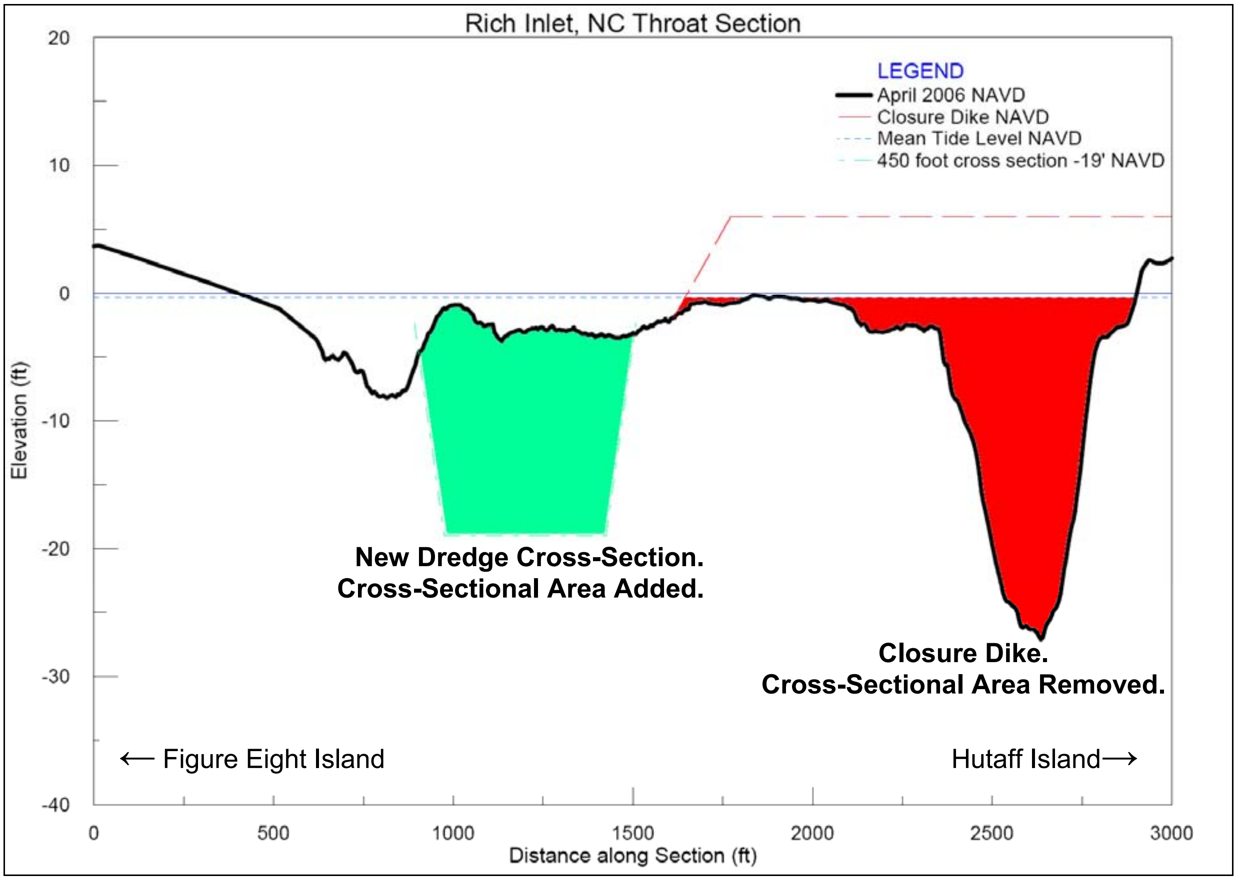



**FIGURE 9-3: Cross-Section of the Inlet Throat.**

### 9.1.4 Side Channels

Flow through Rich Inlet is carried into the Atlantic Intracoastal Waterway (AIWW) primarily through Nixon Channel and Green Channel with some flow migrating through the salt marsh area immediately north of the inlet. Nixon Channel lies to the south of the entrance channel and runs from east to west. Green Channel lies north of the entrance channel and runs from south to north. To ensure a successful relocation of the entrance channel, it is necessary to dredge connecting cuts from the entrance channel in Nixon Channel and Green Channel.

#### 9.1.4.1 Dredging Option 1

Dredging Option 1 appears in Figure 9-4, and features an entrance channel through the middle of Rich Inlet, a connecting cut into Nixon Channel, a connecting cut into Green Channel, and a narrow extension of entrance channel towards the salt marsh bounded by Nixon Channel, Green

Channel, and the Intracoastal Waterway. Although this Dredging Option provides connecting cuts in Nixon Channel and Green Channel, extension of the entrance channel is not necessary to maintain adequate flow through Nixon Channel and Green Channel. Cleary (2008) has noted that the salt marsh facing the entrance of the main channel of Rich Inlet has been eroding. Preliminary Delft3D model results have shown that much of the flow going through Green Channel is directed to and from the entrance channel through the entrance channel extension instead of the Green Channel connecting cut. This could worsen the erosion of the salt marsh and could make the Green Channel connecting cut more difficult to maintain. Finally, the extension of the entrance channel increases the project footprint and the area impacted during construction, with few added benefits. For these reasons, Dredging Option 1 has been dropped from consideration.

**9.1.4.2 Dredging Option 2**

Dredging Options 2A and 2B (Figure 9-5) dredge a new entrance channel through the middle of Rich Inlet. The new entrance channel is located midway between Figure Eight Island and Hutaff Island approximately 1,300 feet southwest of the existing (April 2006) channel. The length of the cut is 3,500 feet, and the bottom width is 500 feet given the old design depth of -17 feet NAVD. The new entrance channel runs along a bearing of 142$^{o}$ / 322$^{o}$ (northwest-southeast). At the northern end of the entrance channel, the dredge cut splits into two smaller channels connecting into Nixon Channel and Green Channel. The connection into Nixon Channel runs on a bearing of 64$^{o}$ / 244$^{o}$ (west-southwest to east-northeast) and has a bottom width of 275 feet given the old design depth of -17 feet NAVD. The connection into Green Channel runs on a bearing of 14$^{o}$ / 194$^{o}$ (north-northeast to south-southwest) and has a bottom width of 225 feet given the old design depth of -17 feet NAVD. Under Dredging Option 2A, the connections to Nixon Channel and Green Channel are 3,800 and 2,000 feet long, respectively. Under the shorter Dredging Option 2B, the connections to Nixon Channel and Green Channel are 1,700 and 1,400 feet long, respectively.

Dredging Options 2A and 2B provide sufficient connections from Nixon Channel and Green Channel into the entrance channel without the unnecessary dredging of Dredging Option 1. Flow into Nixon Channel and Green Channel would occur through the corresponding connecting cuts, and would not increase the erosion observed by Cleary (2008) along the interior salt marsh. At the north end of Beach Road North, seven (7) parcels face Nixon Channel (address numbers 538 to 552). The seven (7) parcels are located at Nixon Channel profiles RIN17+00 to RIN25+00. Due to the shifting of Nixon Channel, these properties are currently experiencing high rates of erosion. The high erosion rates have prompted the placement of sandbags along three (3) of the parcels. Dredging Option 2A can sufficiently address the erosion problem along this area, as detailed in the Delft3D modeling study. Dredging Option 2B cannot, since the deep section of the channel is not moved away from the threatened properties. In Green Channel, the difference in cut volume between Dredging Options 2A and 2B is 17-18%. Thus, the corresponding difference in performance would be negligible. Accordingly, if Dredging Option 2 became the Preferred Dredging Option, the design for Nixon Channel would be Dredging Option 2A, and the design for Green Channel would be Dredging Option 2B.

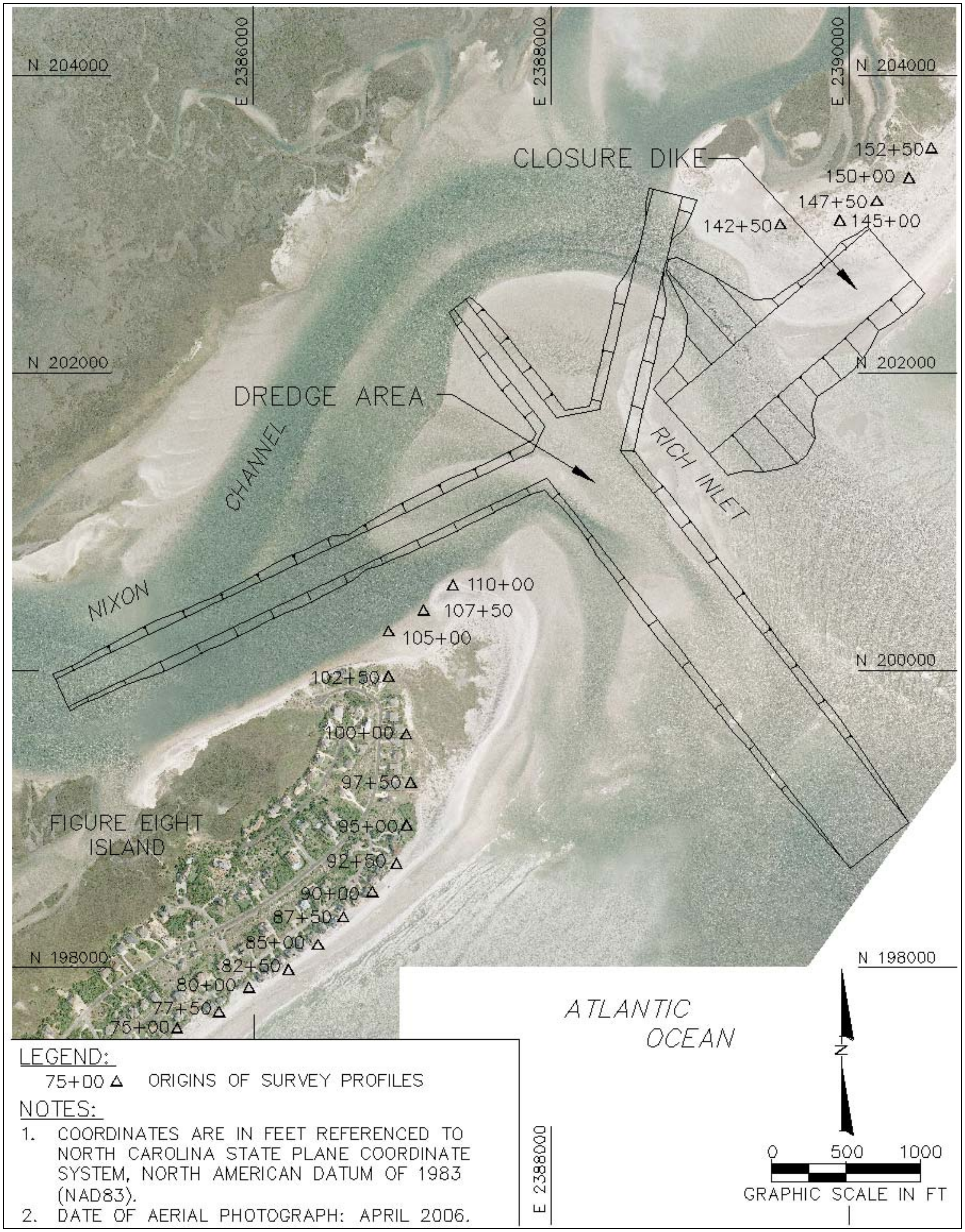



**FIGURE 9-4: Rich Inlet Dredging Option 1 under Alternative 3.**


**FIGURE 9-5: Rich Inlet Dredging Options 2A and 2B under Alternative 3.**

### 9.1.4.3 Dredging Option 3

Dredging Option 3 appears in Figures 9-6 and 9-7. This Dredging Option features only one connecting cut, which runs from the entrance channel into Nixon Channel. Because there is no connecting cut into Green Channel, it does not provide for adequate flow into Green Channel. Presently, Green Channel connects directly into the existing channel. However, if Dredging Option 3 were constructed with the closure dike across the existing channel, there would be no direct connection between Green Channel and the relocated entrance channel, as shown on the contour map in Figure 9-7. Thus, among all the Dredging Options proposed, Dredging Option 3 represents the greatest departure from the existing conditions. For this reason, Dredging Option 3 has been dropped from consideration.

### 9.1.4.4 Dredging Option 4

Dredging Options 4A and 4B appear in Figure 9-8. Dredging Options 4A and 4B also dredge a new entrance channel through the middle of Rich Inlet. The seaward end of the entrance channel is at the same location Dredging Options 2A and 2B, and its bearing is the same. However, its length is 4,600 feet. Along the first 3,500 feet, the bottom width is 500 feet given the old design depth of -17 feet NAVD. Along the remainder of the entrance channel, the bottom width is 300 feet given the old design depth of -17 feet NAVD. Where the 500 foot wide section ends, there is a connection into Nixon Channel. This connection runs on the same bearing as Dredging Options 2A and 2B. However, its bottom width is 200 feet given the old design depth of -17 feet NAVD. Under Dredging Options 4A and 4B, the connection to Nixon Channel is 3,800 feet and 1,700 feet long, respectively. There is no direct connection to Green Channel. All side slopes are 1 vertical on 5 horizontal.

Dredging Options 4A and 4B provide a direct connection between Nixon Channel and the entrance channel. The entrance channel ends along a natural channel that runs between Nixon Channel and Green Channel along the salt marsh. The longer entrance channel and this natural channel provide an indirect connection into Green Channel.

The difference between Dredging Options 4A and 4B is the length of the connecting cut into Nixon Channel. For reasons similar to Dredging Option 2, it is necessary to dredge the longer cut into Nixon Channel to address the erosion problem at 538-552 Beach Road North. Accordingly, Dredging Option 4B has been dropped from consideration.

### 9.1.4.5 Preferred Dredging Option

The two viable Dredging Options are Dredging Option 2 and Dredging Option 4A. Dredging Option 4A can reduce the erosional stresses on the north end of Figure Eight Island. However, it does not offer a direct conduit for flow between Green Channel and the entrance channel. Furthermore, it could accelerate erosion along the salt marsh area facing the entrance of the inlet. For this reason, Dredging Option 4A is not the Preferred Dredging Option. Accordingly, the Preferred Dredging Option for Rich Inlet is Dredging Option 2, with the following variations:


**FIGURE 9-6: Rich Inlet Dredging Option 3 under Alternative 3.**

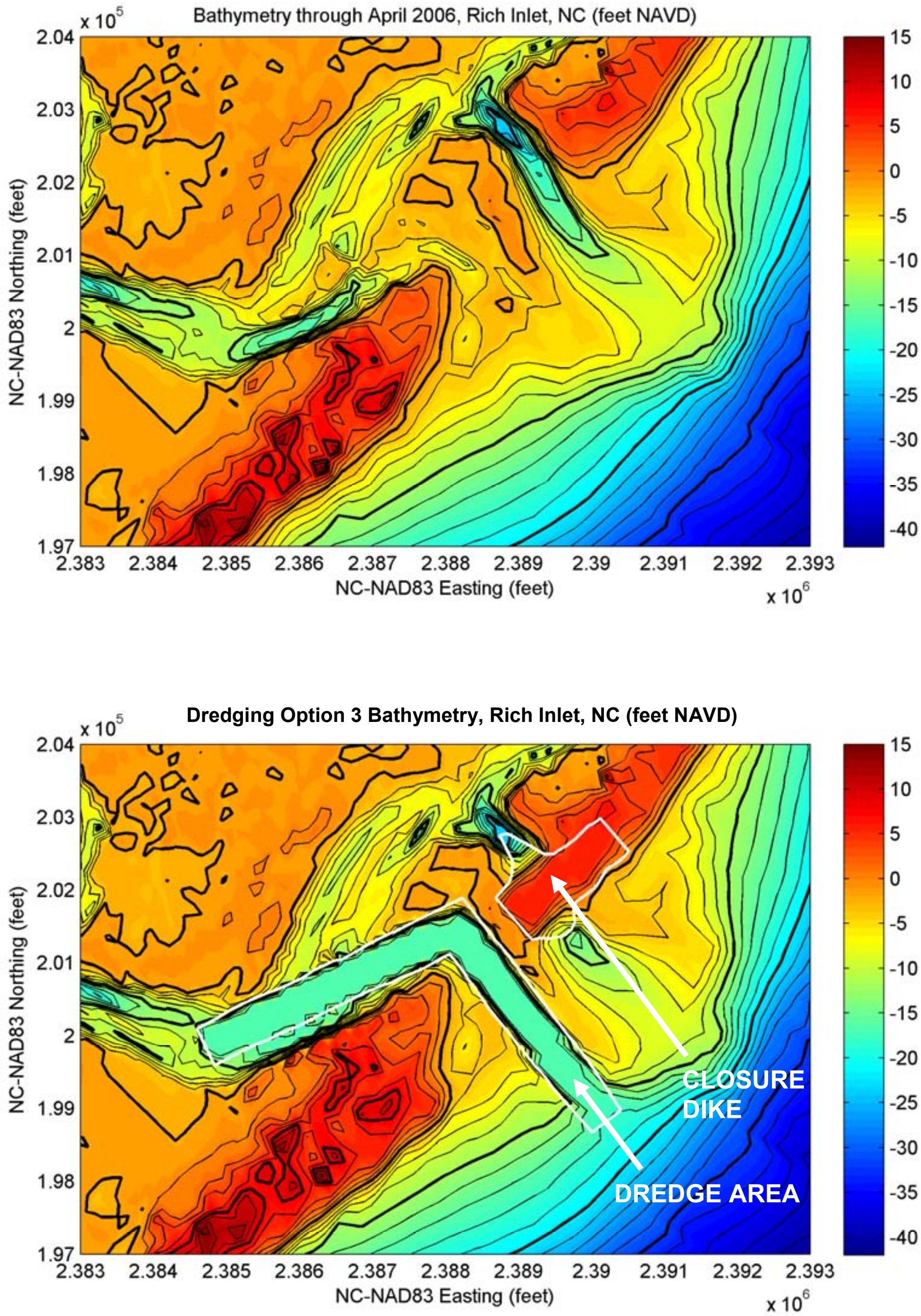



**FIGURE 9-7: Bathymetric Contours Given Rich Inlet Dredging Option 3 under Alternative 3.**


**FIGURE 9-8: Rich Inlet Dredging Options 4A and 4B under Alternative 3.**

- Dredging Option 2A inside the entrance channel and Nixon Channel.
- Dredging Option 2B inside the connection to Green Channel.

By dredging a long cut through Nixon Channel, Dredging Option 2A is able to reduce the erosion stress at 538-552 North Beach Road by shifting the flow towards the middle of the channel. Near Green Channel, the shorter Dredging Option 2B eliminates dredging in the interior of Green Channel, while maintaining a conduit for flow between Green Channel and the entrance channel.

To make the project easier to construct, the design depth was changed from -17 to -19 feet NAVD. This change allowed reduction in the bottom width from 500 to 450 feet in the entrance channel and 275 to 240 feet in the Nixon Channel cut. To improve the efficiency of the Green Channel connecting cut, the centerline of the cut was shifted slightly to the west, and the bottom width was changed to 300 feet. This change was able to ensure that the amount of flow going through Green Channel would be similar to the present conditions.

### 9.1.5 Channel Design Summary under Alternative 3

The Preferred Dredging Option for Rich Inlet features an entrance channel, with 2 side cuts connecting the entrance channel to Nixon Channel and Green Channel. Based on the inlet stability analysis, modeling results, and inquiries regarding feasible dredge depths, the design of Alternative 3's relocated channel in Rich Inlet may be summarized by the following:

- Dredge Depth = -19 feet NAVD + 1 foot overdepth.

- Bottom width & length:

    - Entrance Channel (inlet throat) = 450 feet x 3,500 feet.
    - Nixon Channel = 240 feet x 3,800 feet.
    - Green Channel = 300 feet x 1,400 feet.

- Dredge Volume = 1,773,300 c.y. + 150,400 c.y. overdepth based on the April 2006 survey = 1,923,700 c.y. total. The Nixon Channel connector contains 42,300 c.y. of clay.

- Closure Dike:

    - Crest Elevation = +6 feet NAVD + 0.5 foot tolerance.
    - Crest Width = 450 feet.
    - Side Slopes = 1 vertical on 20 horizontal (assumed).
    - Volume = 513,700 c.y. + 32,000 c.y. tolerance based on April 2006 survey = 545,700 c.y. total.

- Upland Disposal:
    - 42,300 c.y. clay from Nixon Channel

- Oceanfront Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.
  - Side Slopes:
    - 1 vertical on 5 horizontal in the dune fill area
    - 1 vertical on 10 horizontal above mean high water (+1.7' NAVD)
    - 1 vertical on 20 horizontal (assumed) below mean high water
  - Fill Length = 12,501 feet.
  - Volume = 1,131,900 c.y. + 132,400 c.y. tolerance based on April 2007 survey = 1,264,300 c.y. total.

- Nixon Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.
  - Side Slopes:
    - 1 vertical on 5 horizontal
  - Fill Length = 1,800 feet.
  - Volume = 65,000 c.y. + 6,400 c.y. tolerance based on October 2005 surveys = 71,400 c.y. total.

A plan view of the dredge cuts and disposal areas appear in Figures 9-8 to 9-10. Typical cross-sections appear in Figures 9-11 and 9-12. Dredging volumes are detailed in Sub-Appendix B.

### 9.1.6 Beach Fill Design under Alternative 3

Based on the April 2006 survey, Alternative 3's Preferred Dredging Option will remove approximately 1,773,300 c.y. from Rich Inlet. Filling the closure dike will require 513,700 c.y., based on the April 2006 survey. Also, a pocket of clay, containing 42,300 c.y. was discovered in a section of the Nixon Channel connector which is not beach compatible and would have to be deposited in an upland disposal site located on the south side of the intersection of Nixon Channel and the AIWW. Accordingly, there will be at least 1,217,300 c.y. available to nourish the Figure Eight Island ocean shoreline north of Bridge Road and the Nixon Channel shoreline.

The following options were considered for beach disposal areas:

1. Fill along the entire length of Beach Road (F-5+00 to 105+00, 22,000 feet), and no fill along Nixon Channel.

2. Fill from the intersection of Beach Road and Bayberry Place to Rich Inlet (0+00 to 105+00, 10,500 feet), and no fill along Nixon Channel.

3. Fill from the intersection of Beach Road and Beachbay Lane to Rich Inlet (F90+00 to 105+00, 12,501 feet), with a small fill area along Nixon Channel near the north end of Beach Road (1,800 feet, RIN12+00 to RIN30+00). This option also includes a small amount of dune fill between profiles 77+50 and 95+00 for increased storm protection.


**FIGURE 9-9A: Alternative 3 Preferred Dredging Option and Beach Fill Layout.**

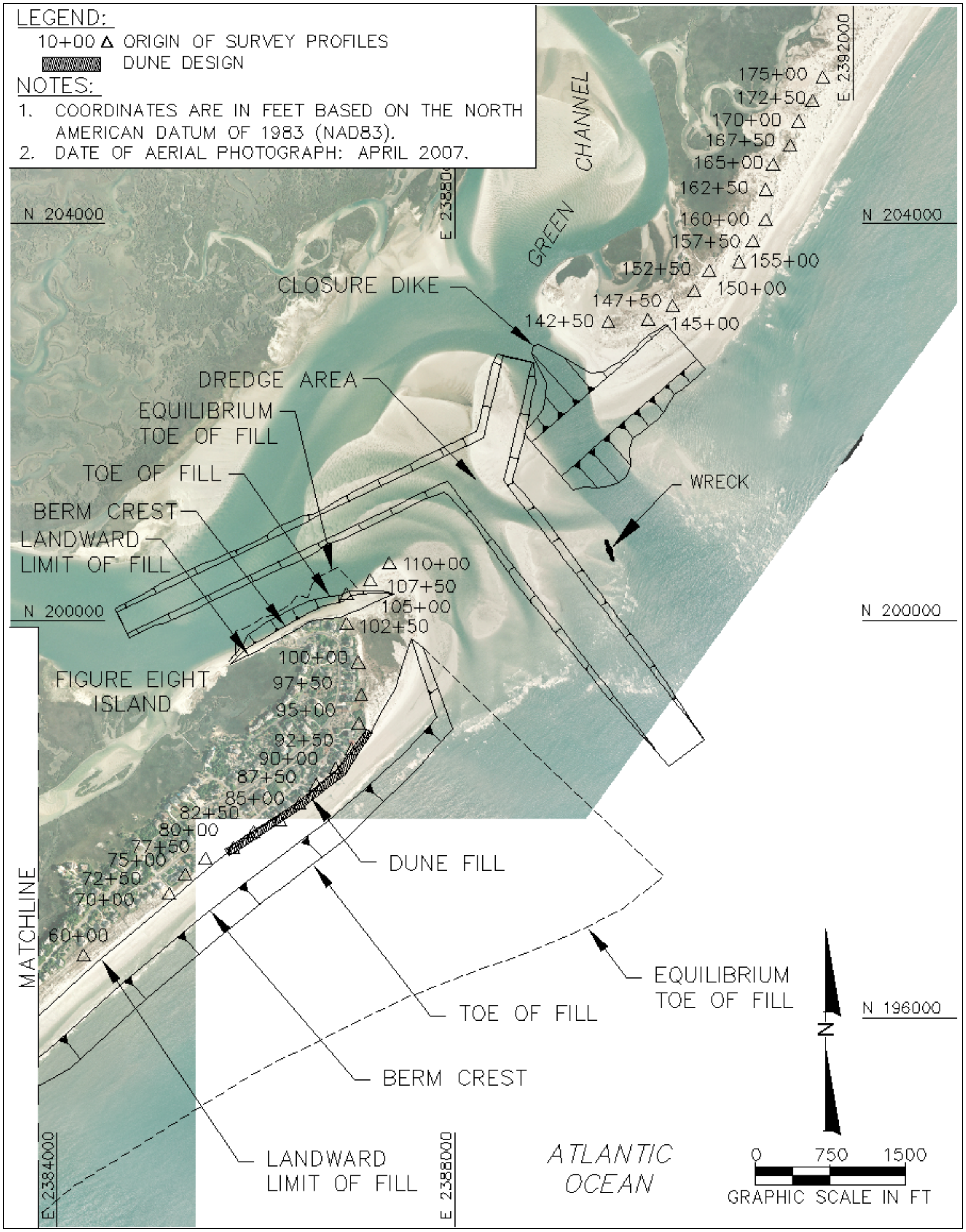



**FIGURE 9-9B: Alternative 3 Preferred Dredging Option and Beach Fill Layout.**

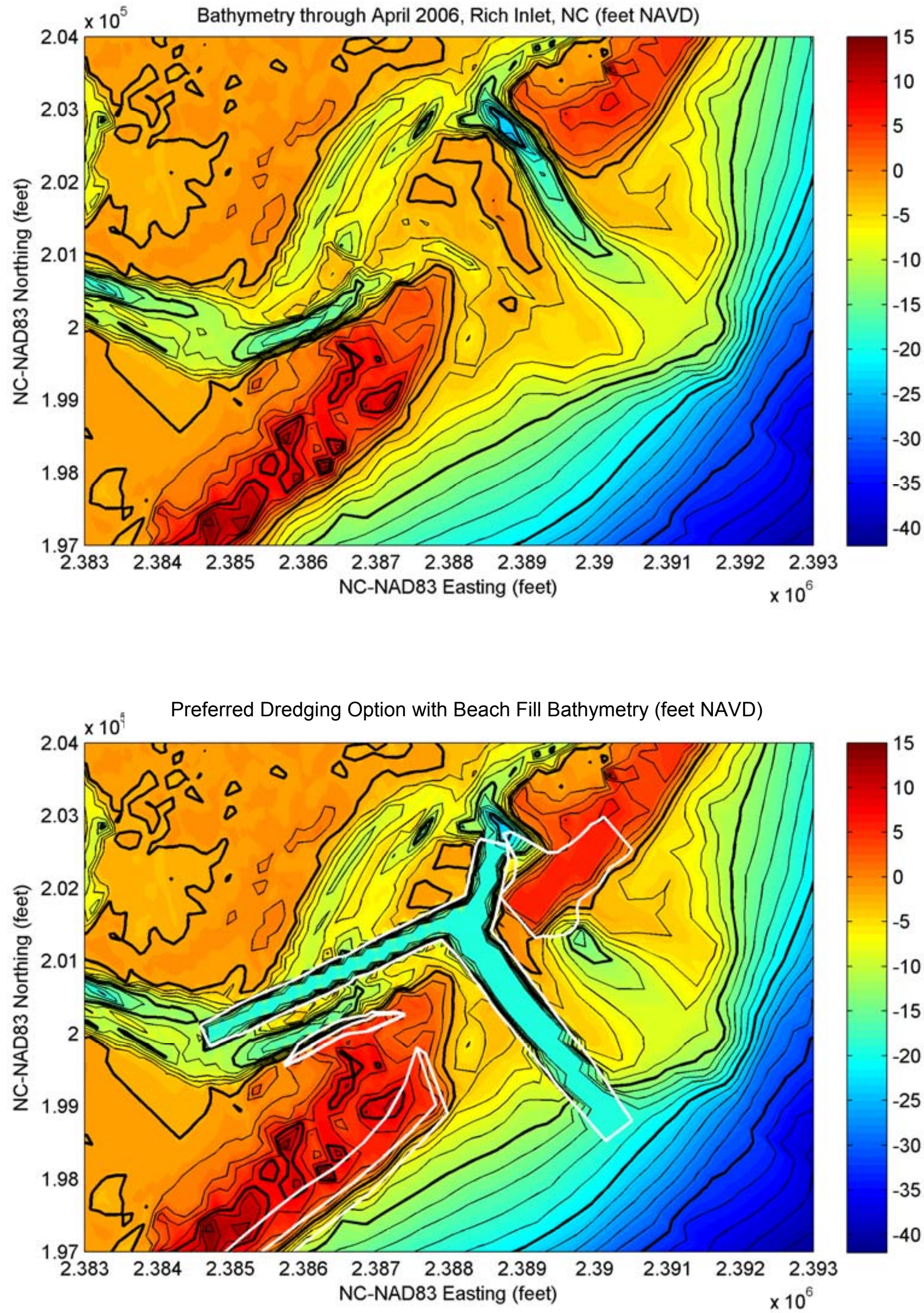



**FIGURE 9-10: Bathymetric Contours Given Preferred Dredging Option under Alternative 3.**

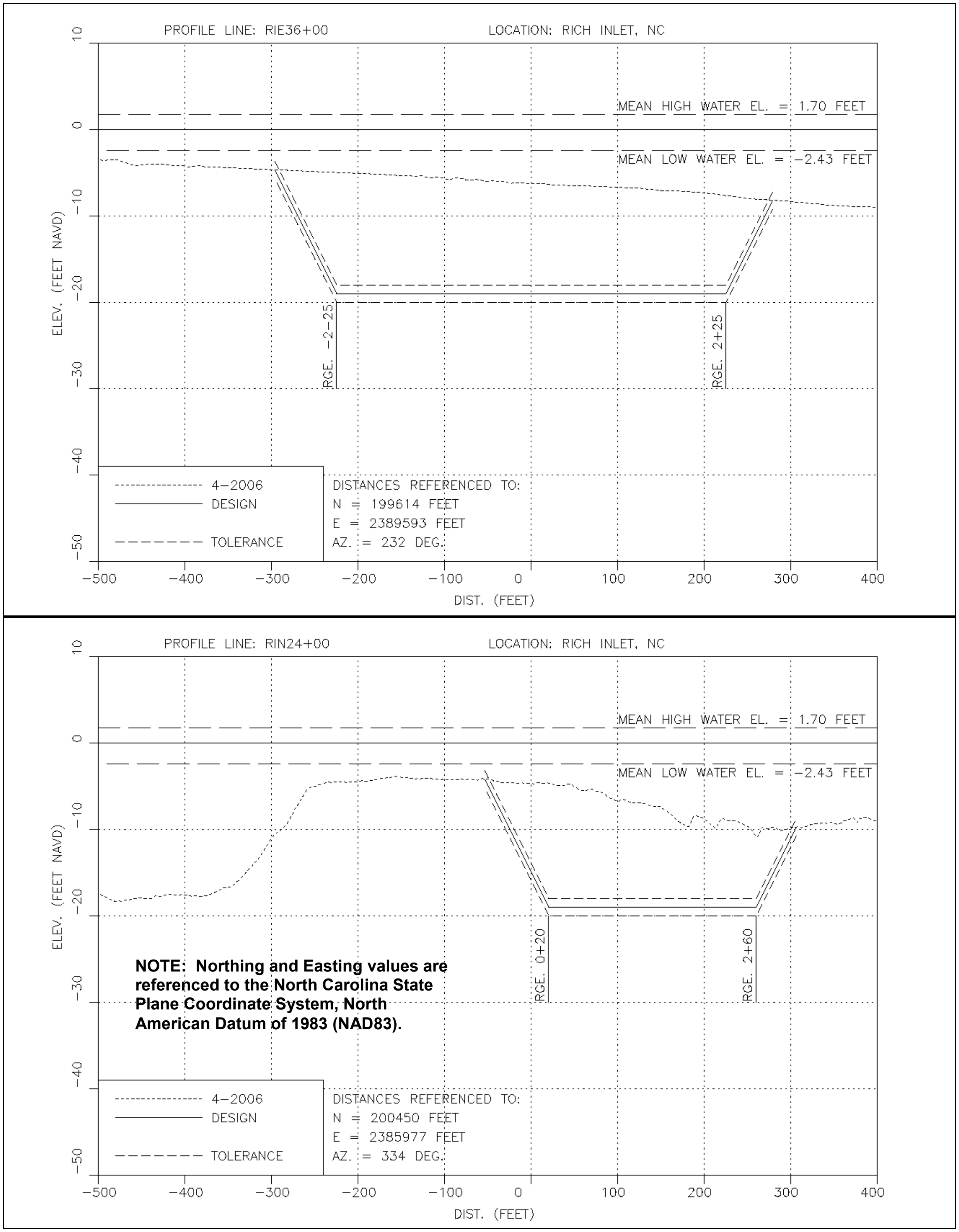



**FIGURE 9-11: Typical Cross-Sections in the Entrance Channel (top) and Nixon Channel (bottom), Alternative 3.**

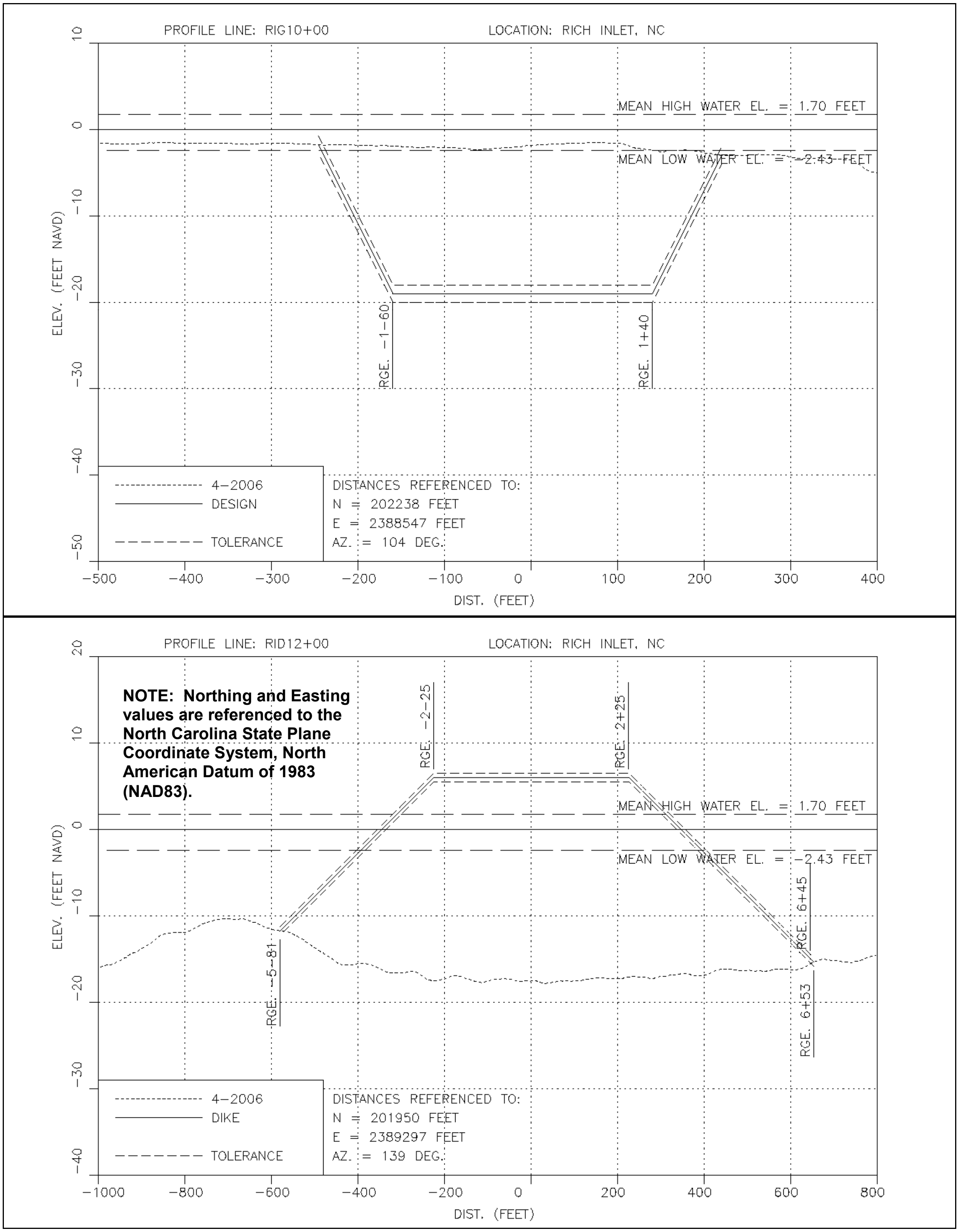



**FIGURE 9-12: Typical Cross-Sections in Green Channel (top) and the Closure Dike (bottom), Alternative 3.**

Alternative 3 utilizes the 3rd option above. Placing fill along the entire length of Beach Road (option 1) using a pipeline or dustpan dredge would increase the cost of dredging, especially if booster pumps were required. On the other hand, starting the fill at the intersection of Beach Road and Bayberry Place (profile 0+00) (option 2) would leave a gap in the managed shoreline between the Mason Inlet disposal area (profiles F0+00 to F100+00) (ATM, 1999) and the Rich Inlet disposal area. Finally, neither the first nor the second fill options address the high erosion area along Nixon Channel. The 3rd fill option places material along Nixon Channel to address the high erosion rates at the north end of Beach Road. In addition, it utilizes the existing maintenance program at Mason Inlet to economically manage the oceanfront shoreline as a whole. Accordingly, the 3rd fill option is the one included in Alternative 3.

#### 9.1.6.1 Cross-Sectional Volume and Sand Compatibility

Cross-section sizes along the oceanfront shoreline are based on the "Worst Case" retreat rates in Table 6-1. The averages of those values by reach are:

- Beachbay Lane to 282 Beach Road North (F90+00 to 40+00), 9.2 feet/year.
- 302 Beach Road North to 530 Beach Road North (50+00 to 100+00), 24.8 feet/year.

The design berm elevation is +6 feet NAVD, which is approximately equal to the seaward toe of dune along the oceanfront beach fill area. The seaward limit of cross-shore spreading is assumed to be equal to the depth of closure, -24 feet NAVD.

The final quantity needed to determine the cross-section size is the overfill factor. The overfill factor indicates the proportion of fill required to compensate for differences between the grain sizes of the fill source and the existing beach. An overfill factor of 1.0 indicates that no extra fill is required. An overfill factor of 1.28 indicates that the fill volume must be increased 28% to achieve the same performance as material identical to the existing beach. Overfill factors in Table 9-1 are based on the beach composites in Table 4-7, the preliminary inlet composite for the dredge cuts, and the Shore Protection Manual (James-Krumbein) Overfill and Renourishment Factor (USACE, 1986). The higher overfill factor, based on the existing material along Figure Eight Island, is 1.044.

**TABLE 9-1**
**OVERFILL FACTORS**
**FIGURE EIGHT ISLAND, NC**

| Composite | Mean Grain Size (mm) | Sorting (Φ) | Overfill Factor Ra |
|---|---|---|---|
| Figure Eight Island (F80+00 to 90+00) | 0.18 | 0.55 | 1.044 |
| Hutaff Island (H1 to H3) | 0.21 | 0.85 | 1.000 |
| Dredge Area (Figure 9-8) | 0.24 | 0.83 | |

Based on the averaged retreat rates above, the design berm elevation (+6' NAVD), the cross-shore spreading limit (-24' NAVD), and an overfill factor of 1.044, cross-section sizes along oceanfront shoreline appear in Table 9-2. Cross-section sizes and fill volumes exclude the upper tolerance.

Cross-section sizes along the Nixon Channel shoreline are based on shoreline retreat rates between 1993 and 2005 (USGS, 1993; NOAA, 2005) (Table 9-3). Full size cross-sections extend 800 feet from profiles RIN17+00 to RIN25+00. The eastern taper section is 500 feet long, extending from profiles RIN12+00 to RIN17+00. The western taper section is 500 feet long, extending from profiles RIN25+00 to RIN30+00. The assumed cross-shore spreading limit along Nixon Channel is also -24 feet NAVD. Although this is deeper than the scour hole along the fill area, the deeper value provides a factor of safety against the high spreading losses that will occur due to the short fill length. Given the averaged retreat rate in Table 9-3, the design berm elevation (+6' NAVD), the assumed cross-shore spreading limit (-24' NAVD), and an overfill factor of 1.044, cross-section sizes along the Nixon Channel shoreline appear in Table 9-4. Cross-section sizes and fill volumes exclude the upper tolerance.

### 9.1.6.2 Profile Shape

The shapes of the construction templates along the beach were based on the post-construction profiles following the 2005 Bogue Inlet Channel Erosion Response Project. Beach slopes on those profiles averaged 1 vertical on 8 horizontal above wading depth, and 1 vertical on 23 horizontal below wading depth.

In the oceanfront fill area, the specified beach slope above the waterline is 1 vertical on 10 horizontal along the oceanfront fill area. For planning purposes, a beach slope of 1 vertical on 20 horizontal below the waterline is assumed. However, it should be noted that contractors are not able to control the beach slope below the waterline. Accordingly, the beach slope below the waterline is strictly an estimate based on the performance of a previous project in the region.

The design dune cross-section along Comber Road and Inlet Hook Road (profiles 77+50 to 95+00) has side slopes of 1 vertical on 5 horizontal. The crest width of the dune cross-section is 25 feet. To prevent sand from blowing into the upland properties, the dune crest elevation will be similar to the existing dune elevations along the dune fill area, which is approximately +15 feet NAVD. Overall, the dune location in Figure 9-8 is an approximation. The exact dune locations and crest elevations will be determined based on the conditions at the project site immediately prior to construction.

In the Nixon Channel fill area, the specified side slope is 1 vertical on 5 horizontal. This slope is roughly based on the existing bank slope along the scour hole. The assumed slope below the waterline is equal to the specified side slope above the waterline. Representative cross-sections along both fill areas appear in Figures 9-13 and 9-14.

## TABLE 9-2

## OCEANFRONT BEACH DISPOSAL AREA, ALTERNATIVE 3
## FIGURE EIGHT ISLAND / RICH INLET, NC

| Profile Line | Fill Length (feet) | Design Retreat Rate (feet/year) | Adjusted Berm Width (feet) | Fill Distribution (c.y./foot) | | | Fill Volume (cubic yards) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Beach | Dune | Total | Beach | Dune | Total |
| F90+00 | | -9.2 | 0 | 0.0 | 0.0 | 0.0 | | | |
| | 1,000 | | | | | | 26,800 | 0 | 26,800 |
| F100+00 | | -9.2 | 46 | 53.5 | 0.0 | 53.5 | | | |
| | 1,001 | | | | | | 53,600 | 0 | 53,600 |
| 0+00 | | -9.2 | 46 | 53.5 | 0.0 | 53.5 | | | |
| | 1,000 | | | | | | 53,500 | 0 | 53,500 |
| 10+00 | | -9.2 | 46 | 53.5 | 0.0 | 53.5 | | | |
| | 1,000 | | | | | | 53,500 | 0 | 53,500 |
| 20+00 | | -9.2 | 46 | 53.5 | 0.0 | 53.5 | | | |
| | 1,000 | | | | | | 53,500 | 0 | 53,500 |
| 30+00 | | -9.2 | 46 | 53.5 | 0.0 | 53.5 | | | |
| | 1,000 | | | | | | 53,500 | 0 | 53,500 |
| 40+00 | | -9.2 | 46 | 53.5 | 0.0 | 53.5 | | | |
| | 1,000 | | | | | | 98,600 | 0 | 98,600 |
| 50+00 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 1,000 | | | | | | 143,600 | 0 | 143,600 |
| 60+00 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 1,000 | | | | | | 143,600 | 0 | 143,600 |
| 70+00 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 250 | | | | | | 35,900 | 0 | 35,900 |
| 72+50 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 250 | | | | | | 35,900 | 0 | 35,900 |
| 75+00 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 250 | | | | | | 35,900 | 0 | 35,900 |
| 77+50 | | -24.8 | 124 | 143.6 | 8.7 | 152.3 | | | |
| | 250 | | | | | | 35,900 | 3,300 | 39,200 |
| 80+00 | | -24.8 | 124 | 143.6 | 17.4 | 161.0 | | | |
| | 250 | | | | | | 35,900 | 4,100 | 40,000 |
| 82+50 | | -24.8 | 124 | 143.6 | 15.1 | 158.7 | | | |
| | 250 | | | | | | 35,900 | 3,500 | 39,400 |
| 85+00 | | -24.8 | 124 | 143.6 | 12.8 | 156.4 | | | |
| | 250 | | | | | | 35,900 | 3,700 | 39,600 |
| 87+50 | | -24.8 | 124 | 143.6 | 17.0 | 160.6 | | | |
| | 250 | | | | | | 35,900 | 4,800 | 40,700 |
| 90+00 | | -24.8 | 124 | 143.6 | 21.2 | 164.8 | | | |
| | 250 | | | | | | 35,900 | 4,600 | 40,500 |
| 92+50 | | -24.8 | 124 | 143.6 | 15.8 | 159.4 | | | |
| | 250 | | | | | | 35,900 | 3,300 | 39,200 |
| 95+00 | | -24.8 | 124 | 143.6 | 10.5 | 154.0 | | | |
| | 250 | | | | | | 35,900 | 0 | 35,900 |
| 97+50 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 250 | | | | | | 35,900 | 0 | 35,900 |
| 100+00 | | -24.8 | 124 | 143.6 | 0.0 | 143.6 | | | |
| | 250 | | | | | | 26,900 | 0 | 26,900 |
| 102+50 | | -24.8 | 62 | 71.8 | 0.0 | 71.8 | | | |
| | 250 | | | | | | 9,000 | 0 | 9,000 |
| 105+00 | | -24.8 | 0 | 0.0 | 0.0 | 0.0 | | | |
| Oceanfront Profiles F90+00 to 105+00 | 12,501 | | | 91.7 | 2.2 | 93.9 | 1,146,900 | 27,300 | 1,174,200 |

**TABLE 9-3**
**SHORELINE CHANGES ON THE SOUTH SIDE OF NIXON CHANNEL**

| Profile Line | Profile Origin (NC-NAD83) Easting (feet) | Northing (feet) | Azimuth (deg.) | Shoreline Changes (feet/year) March 1993 to October 2005 | October 1996 To October 2005 | DESIGN |
|---|---|---|---|---|---|---|
| RIN12+00 | 2387059.4 | 200966.8 | 334.5 | -N/A- | 7.1 | 7.1 |
| RIN13+00 | 2386969.2 | 200923.7 | 334.5 | -N/A- | -9.3 | -9.3 |
| RIN14+00 | 2386879.0 | 200880.6 | 334.5 | -N/A- | -14.9 | -14.9 |
| RIN15+00 | 2386788.7 | 200837.5 | 334.5 | -N/A- | -22.5 | -22.5 |
| RIN16+00 | 2386698.5 | 200794.4 | 334.5 | -N/A- | -N/A- | -12.8 |
| RIN17+00 | 2386608.2 | 200751.3 | 334.5 | -3.0 | -N/A- | -3.0 |
| RIN18+00 | 2386518.0 | 200708.2 | 334.5 | -1.8 | -N/A- | -1.8 |
| RIN19+00 | 2386427.8 | 200665.1 | 334.5 | -7.4 | -N/A- | -7.4 |
| RIN20+00 | 2386337.5 | 200622.0 | 334.5 | -8.2 | -N/A- | -8.2 |
| RIN21+00 | 2386247.3 | 200578.9 | 334.5 | -8.8 | -N/A- | -8.8 |
| RIN22+00 | 2386157.1 | 200535.8 | 334.5 | -8.6 | -N/A- | -8.6 |
| RIN23+00 | 2386066.8 | 200492.7 | 334.5 | -8.8 | -N/A- | -8.8 |
| RIN24+00 | 2385976.6 | 200449.6 | 334.5 | -8.5 | -N/A- | -8.5 |
| RIN25+00 | 2385886.4 | 200406.5 | 334.5 | -9.8 | -N/A- | -9.8 |
| RIN26+00 | 2385796.1 | 200363.4 | 334.5 | -10.8 | -N/A- | -10.8 |
| RIN27+00 | 2385705.9 | 200320.3 | 334.5 | -9.4 | -N/A- | -9.4 |
| RIN28+00 | 2385615.6 | 200277.2 | 334.5 | -8.7 | -N/A- | -8.7 |
| RIN29+00 | 2385525.4 | 200234.1 | 334.5 | -8.6 | -N/A- | -8.6 |
| RIN30+00 | 2385435.2 | 200191.0 | 334.5 | -7.7 | -N/A- | -7.7 |
| AVERAGE | | | | | | -8.6 |

## TABLE 9-4

## NIXON CHANNEL BEACH DISPOSAL AREA
## ALTERNATIVE 3
## FIGURE EIGHT ISLAND / RICH INLET, NC

| Profile Line | Fill Length (feet) | Design Retreat Rate (feet/year) | Adjusted Berm Width (feet) | Beach Fill Distr. (c.y./foot) | Beach Fill Volume (c.y.) |
|---|---|---|---|---|---|
| RIN12+00 | | 0.0 | 0 | 0.0 | |
| | 100 | | | | 500 |
| RIN13+00 | | -8.6 | 9 | 9.9 | |
| | 100 | | | | 1,500 |
| RIN14+00 | | -8.6 | 17 | 19.8 | |
| | 100 | | | | 2,500 |
| RIN15+00 | | -8.6 | 26 | 29.8 | |
| | 100 | | | | 3,500 |
| RIN16+00 | | -8.6 | 34 | 39.7 | |
| | 100 | | | | 4,500 |
| RIN17+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN18+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN19+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN20+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN21+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN22+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN23+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN24+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 5,000 |
| RIN25+00 | | -8.6 | 43 | 49.6 | |
| | 100 | | | | 4,500 |
| RIN26+00 | | -8.6 | 34 | 39.7 | |
| | 100 | | | | 3,500 |
| RIN27+00 | | -8.6 | 26 | 29.8 | |
| | 100 | | | | 2,500 |
| RIN28+00 | | -8.6 | 17 | 19.8 | |
| | 100 | | | | 1,500 |
| RIN29+00 | | -8.6 | 9 | 9.9 | |
| | 100 | | | | 500 |
| RIN30+00 | | -8.6 | 0 | 0.0 | |
| Nixon Chan. Profiles RIN12+00 to RIN30+00 | 1,800 | | | 36.1 | 65,000 |

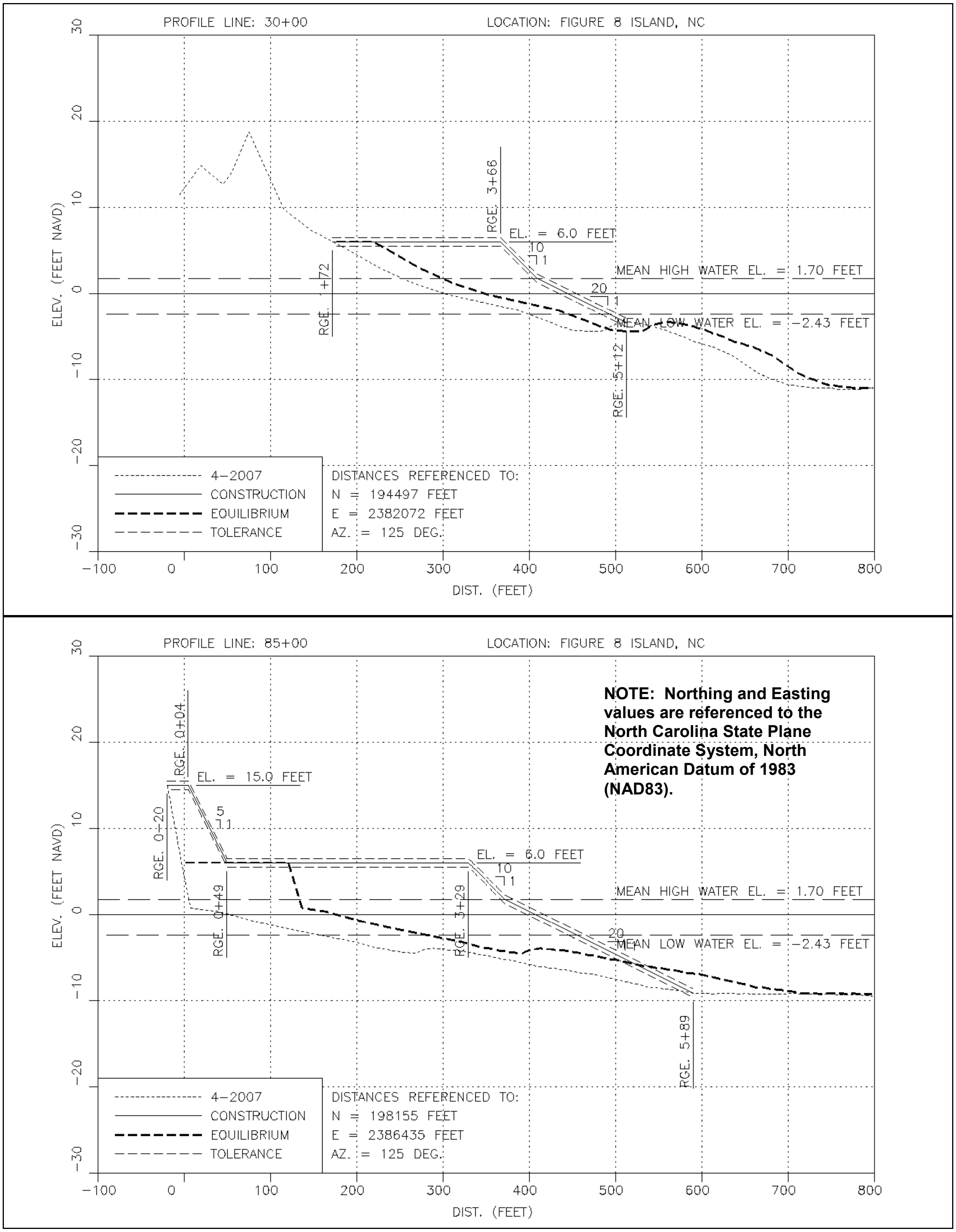



**FIGURE 9-13: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 3.**

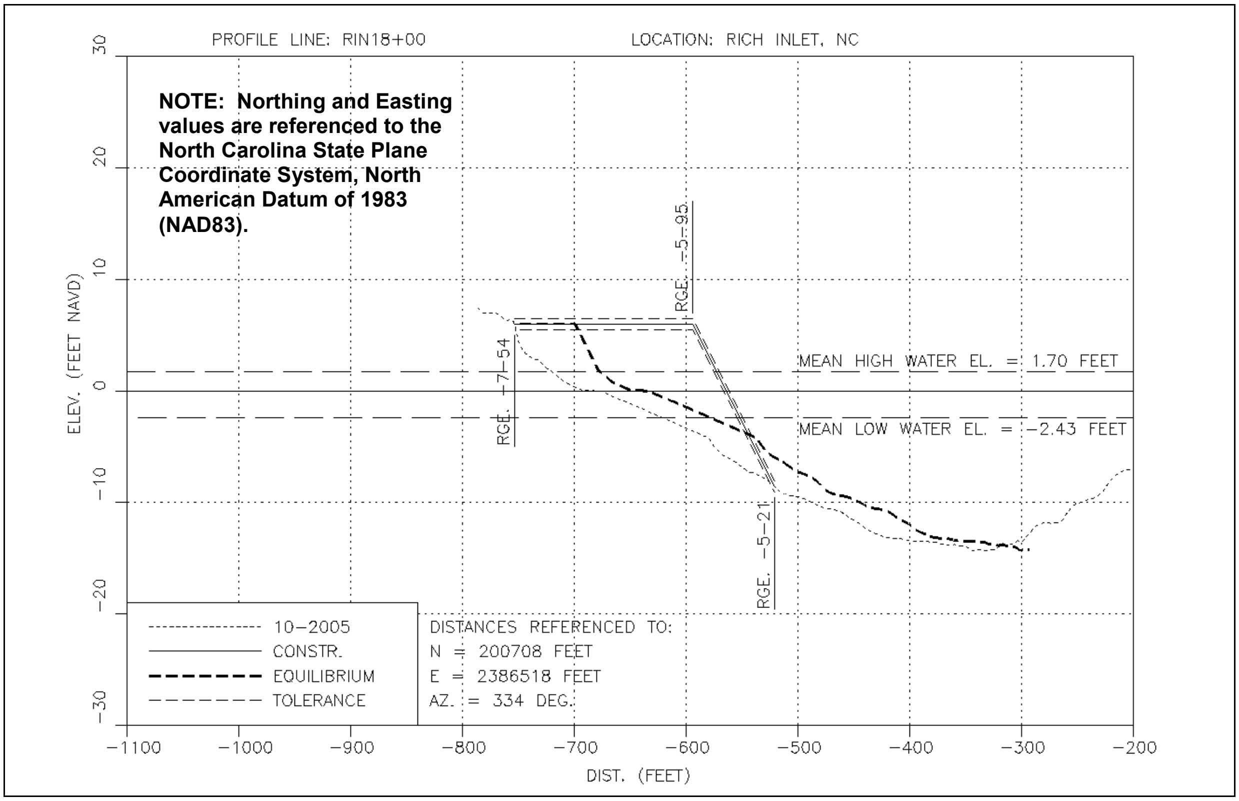



**FIGURE 9-14: Representative Cross-Section along the Nixon Channel Fill Area, Alternative 3.**

## 9.2 Alternative 4 –Beach Nourishment without Inlet Management

Alternative 4 would include a beach fill along the ocean shoreline between Rich Inlet and Bridge Road and a fill along the Nixon Channel shoreline immediately behind the north end of Figure Eight Island and periodic nourishment to maintain the fills. The size of the beach fill along the ocean shoreline associated with Alternative 3 was dictated by the volume of material that would be removed to move the inlet ocean bar channel to a preferred position and alignment and modify the channels leading into both Nixon and Green Channels. For Alternative 4, the size of the beach fill was based on the modeled performance of a fill between Rich Inlet and Bridge Road without any modifications to Rich Inlet. In this regard, the size of the beach fill modeled under Alternative 4 was the same as Alternative 3, however, analysis of the model results found this beach fill to be over designed for the area between stations F90+00 and 80+00 and under designed for the area north of station 80+00. As a result, the beach fill under Alternative 4 was modified to address shoreline erosion issues resulting in a smaller initial beach fill between F90+00 and 80+00 and a larger fill between 80+00 and 100+00. Since Alternative 4 does not include any modification to the Rich Inlet ocean bar channel, material to construct and maintain the beach fills would have to be obtained from other sources which are evaluated below.

Also, due to the high rates of loss from the fill obtained from the model results for the area between 80+00 and 100+00, the beach fill design for Alternative 4 was based on a three-year periodic nourishment cycle. The total initial beach fill volume along the ocean shoreline from Rich Inlet to Bridge Road would be 864,300 cubic yards. The beach fill along Nixon Channel would be the same as Alternative 3 or 65,000 cubic yards. Periodic nourishment would occur every 3 years and would require a total of 670,000 cubic yards. Included in this total is 18,000 cubic yards to nourish the Nixon Channel shoreline and 50,000 cubic yards for the transition fill between stations 100+00 and 105+00. Beach fill placement rates and design berm widths for Alternative 4 are provided in Table 9.5.

**Table 9.5. Alternative 4 beach fill placement volumes and design berm widths**

| Shoreline Segment (Baseline Stations) | Placement Volume (cy/lf) | Design Berm Width (ft) |
|---|---|---|
| 105+00 to 100+00 (transition) | 0 to 200 | 0 to 172 |
| 100+00 to 82+50 | 200 | 172 |
| 82+50 to 80+00 (transition) | 200 to 100 | 172 to 86 |
| 80+00 to 70+00 | 100 | 86 |
| 70+00 to 60+00 (transition) | 100 to 50 | 86 to 43 |
| 60+00 to 30+00 | 50 | 43 |
| 30+00 to 20+00 (transition) | 50 to 20 | 43 to 17 |
| 20+00 to F100+00 | 20 | 17 |
| F100+00 to F90+00 (transition) | 20 to 0 | 17 to 0 |

Material to construct and maintain the beach fill under Alternative 4 would be derived from maintenance dredging of the existing permit area in Nixon Channel, the potential offshore borrow areas identified by Dr. Cleary as described in Chapter 3 of this document, and the three northern AIWW disposal sites also discussed in Chapter 3. Due to the relative small volume available from the three AIWW disposal sites, these sites would be held in reserve and only used for periodic nourishment if the volume of material shoaling the existing permit area in Nixon Channel is insufficient to meet nourishment requirements or other concerns over the removal of the material from Nixon Channel prevent its use. Also, the relatively high rate of periodic nourishment rates for Alternative 4 indicated by the model results would require the continued use of the offshore borrow sites in order to satisfy the nourishment requirements.

## 9.3 Alternative 5A – Terminal Groin with Beach Fill from Nixon Channel

During the 2011 legislation session, the North Carolina Legislature passed Session Law 2011-387, Senate Bill 110 which allows consideration of terminal groins adjacent to tidal inlets. The legislation limited the number of terminal groins to four (4) statewide and included a number of provisions and conditions that must be met in order for the groins to be approved and permitted.

The purpose of the terminal groin is to create a permanent accretion fillet immediately adjacent to the inlet by controlling tide induced or influenced sediment transport off the extreme north end of the island. In so doing, the groin and associated accretion fillet would create a relatively stable shoreline position immediately south of the inlet with an alignment comparable to the shoreline farther south. The elimination or reduction in tide induced or influenced sediment transport off the extreme north end of the island should improve the performance and longevity of beach fills placed on the northern half of Figure Eight Island but would not prevent littoral transport, i.e., wave induced sediment transport, from moving past the terminal groin and into Rich Inlet. In this regard, a terminal groin would not address shoreline management problems along the entire island therefore; a shoreline management alternative that includes a terminal groin must include beach nourishment.

### 9.3.1 Groin Dimensions

The terminal groin location is based on the island's 1998 and 1970 shorelines (Figure 9-15). The 1998 shoreline is based on the September 1998 Light Detection and Ranging (LIDAR) survey by NOAA, and represents the beginning of the present erosional period. The 1970 shoreline is digitized from the 1970 quad map for Rich Inlet (USGS, 1970). The landward half of the groin follows the 1970 inlet shoreline. The seaward end of the groin lies 700 feet from the April 2007 shoreline.

Figure 9-16A shows possible beach fill dimensions immediately adjacent to the terminal groin, which are discussed further below. Figure 9-16B provides a side view of the top elevation of the groin from its landward end to its seaward end.

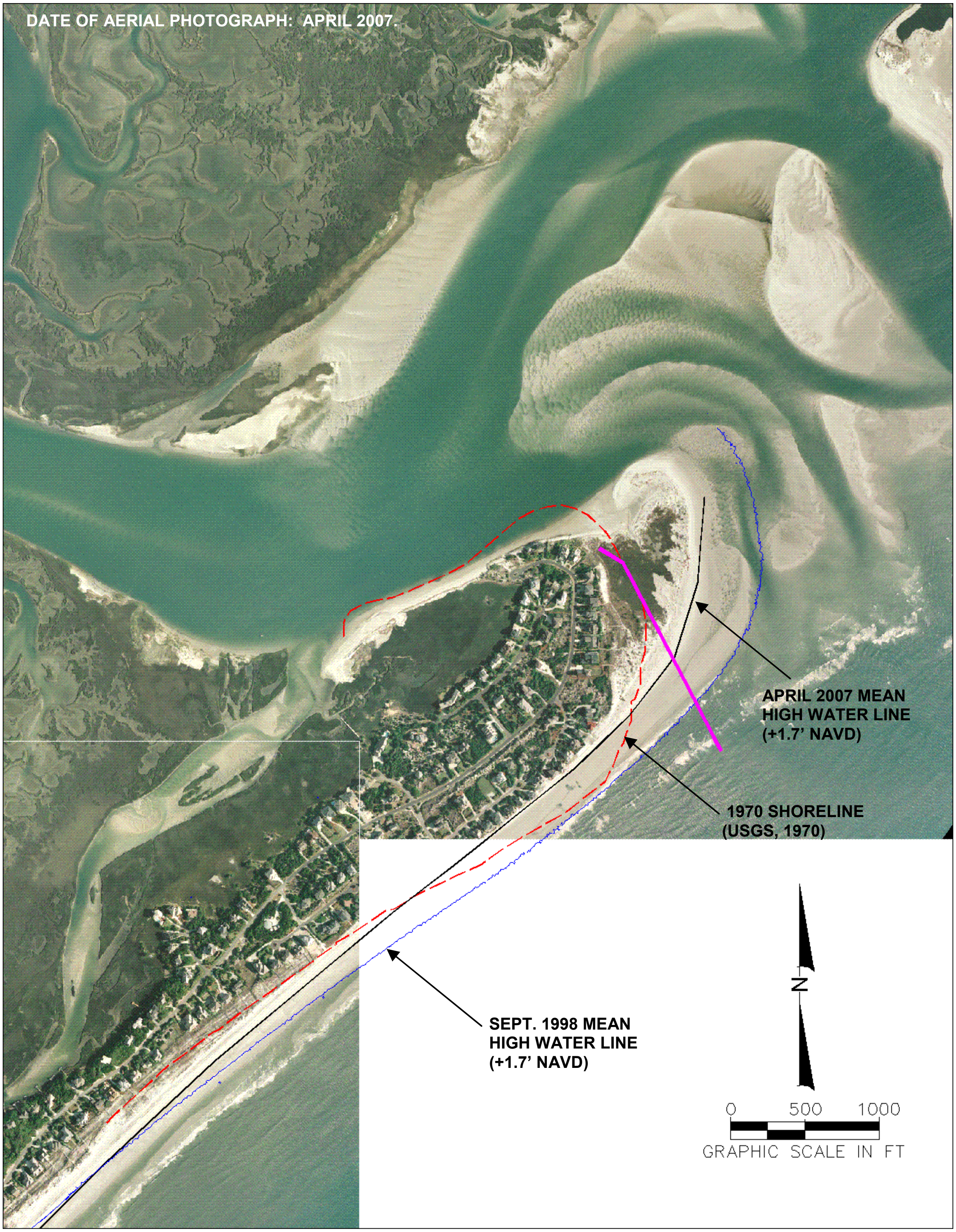



**FIGURE 9-15: Terminal Groin Layout Based on 1970 and 1998 Shorelines.**

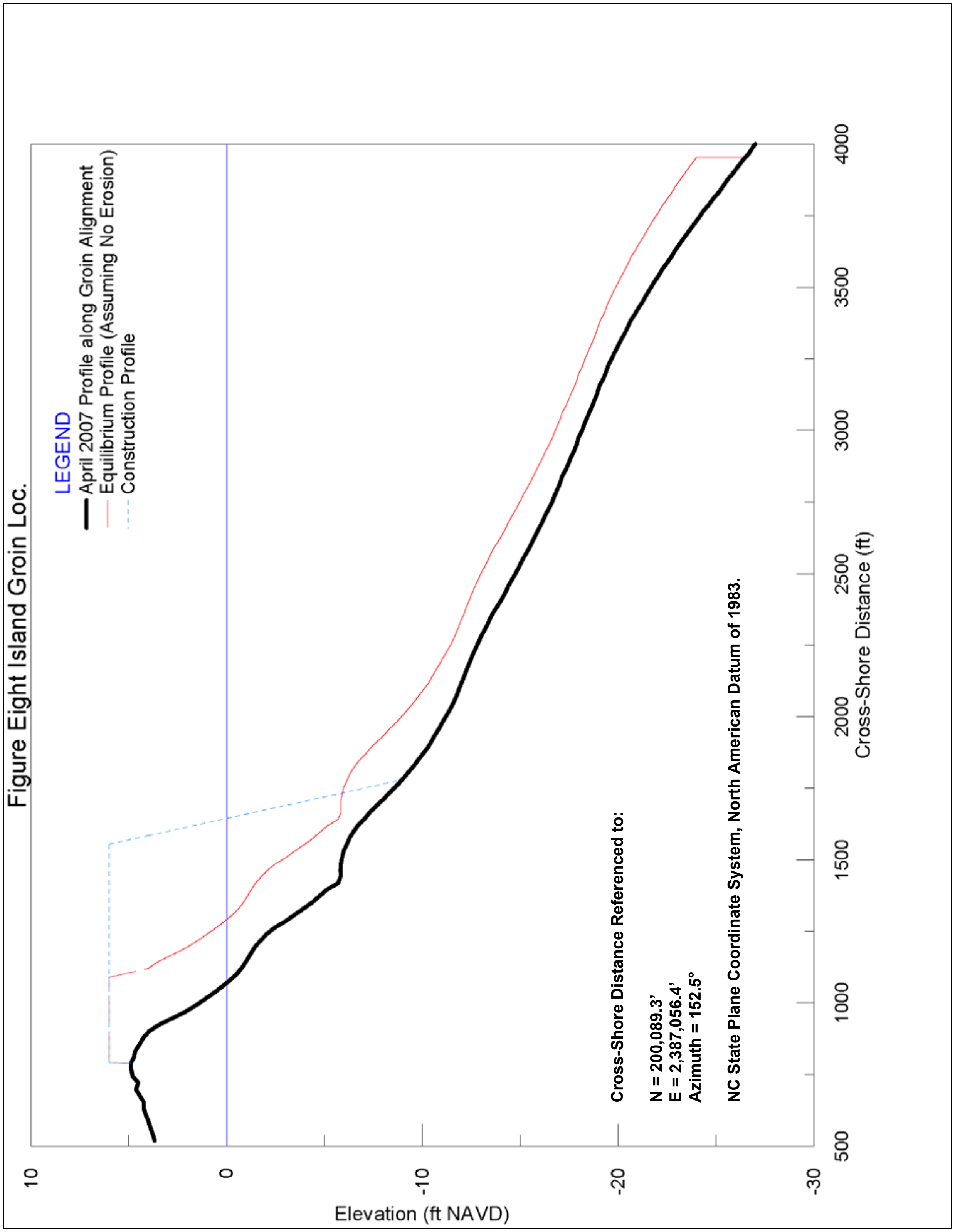



**FIGURE 9-16A: Beach Fill Cross-Section Adjacent to Groin.**

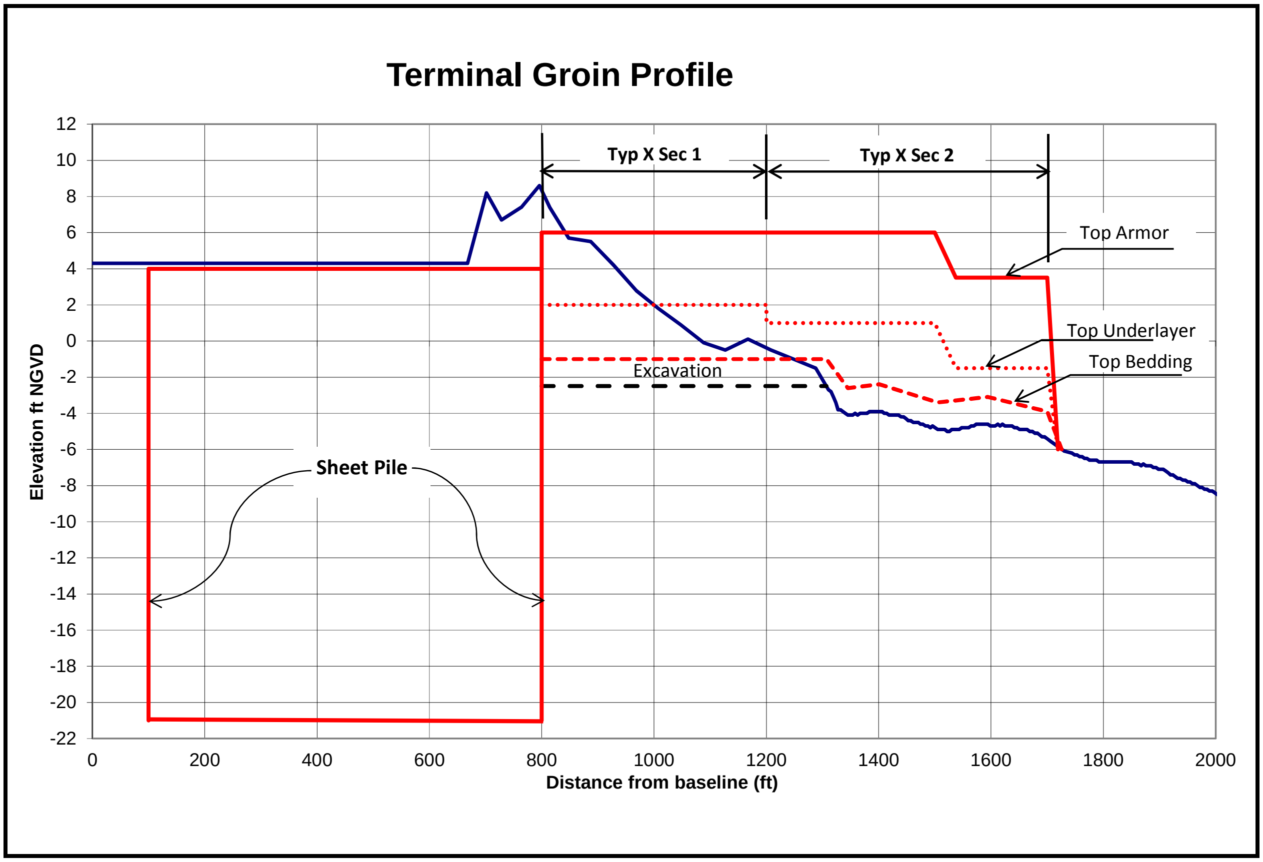



**FIGURE 9-16B: Groin Elevation with Adjacent Beach Cross-Sections.**

The crest elevation of the groin is intended to follow the existing topography along the landward half of the structure (Figure 9-16B). Along the seaward half of the structure, the crest elevation will follow the cross-section of the accompanying beach fill except near its seaward end. At this location, the groin crest elevation will be +3.5' NAVD to allow its visibility at all phases of the tide. In addition, a navigation aid, consisting of a three-pile dolphin with light, will be installed at the seaward end of the groin.

### 9.2.1.1 Structural Design of the Terminal Groin

The following description of the design of the terminal groin is based on preliminary design considerations and the latest survey information which are subject to change during the preparation of detailed plans and specifications. However, the size of the structures footprint and the required construction corridor presented below are representative of the final design.

The total length of the terminal groin would be around 1,600 feet of which only 700 feet would project seaward of the existing mean high water (MHW) shoreline. The landward 700 feet of the structure would be constructed with sheet pile, either steel or concrete, and would have a top elevation of +4 feet NAVD which is slightly below the existing ground elevation. The landward end of the groin would terminate near the existing Nixon Channel shoreline. To account for possible scour in this location, the landward portion of the sheet pile section would be protected by a rubble scour protection apron that would begin about 100 feet from the end of the structure and wrap around both sides. The toe apron would be installed at a depth of approximately 0 ft NAVD and would require the excavation of approximately 600 cubic yards. Material excavated for the toe apron would be used to bury the toe protection stone following placement. A total of 14,000 to 18,000 square feet of sheet pile would be required depending on the final design characteristics. The seaward 900 feet of the structure would be constructed with stone in a typical rubblemound fashion. A profile of the terminal groin is shown on Figure 9-16B with typical cross-sections of the rubblemound portion designated as Typical Cross-sections 1 and 2 shown in Figures 9-17 and 9-18, respectively. Typical Cross-section 1 would cover 400 feet of the structure beginning at a point approximately 200 feet landward of the MHW shoreline and would have a crest elevation of +6 feet NAVD. Typical Cross-section 2 would extend seaward of that point and terminate at a depth of approximately -6 feet NAVD based on the latest profile survey. The first 400 feet of Typical Cross-section 2 would have a top elevation of +6 feet NAVD and would slope down to a top elevation of +3.5 feet on the seaward end. Based on this preliminary design, construction of the rubblemound portion of the terminal groin would require around 16,000 tons of stone.

The concept design for the terminal groin presented here is intended to allow littoral sand transport to move over, around, and through the structure once the accretion fillet south of the terminal groin is artificially filled. This would be accomplished by setting the maximum crest elevation of the terminal groin to +6 feet NAVD, which is an elevation equal to approximately the natural berm elevation, limiting its effective length to 700 feet, and constructing the structure with large voids between adjacent stones. While the seaward portion of the groin should be visible at all stages of the tide, the seaward end of the terminal groin would be marked by a US Coast Guard approved navigation aid.

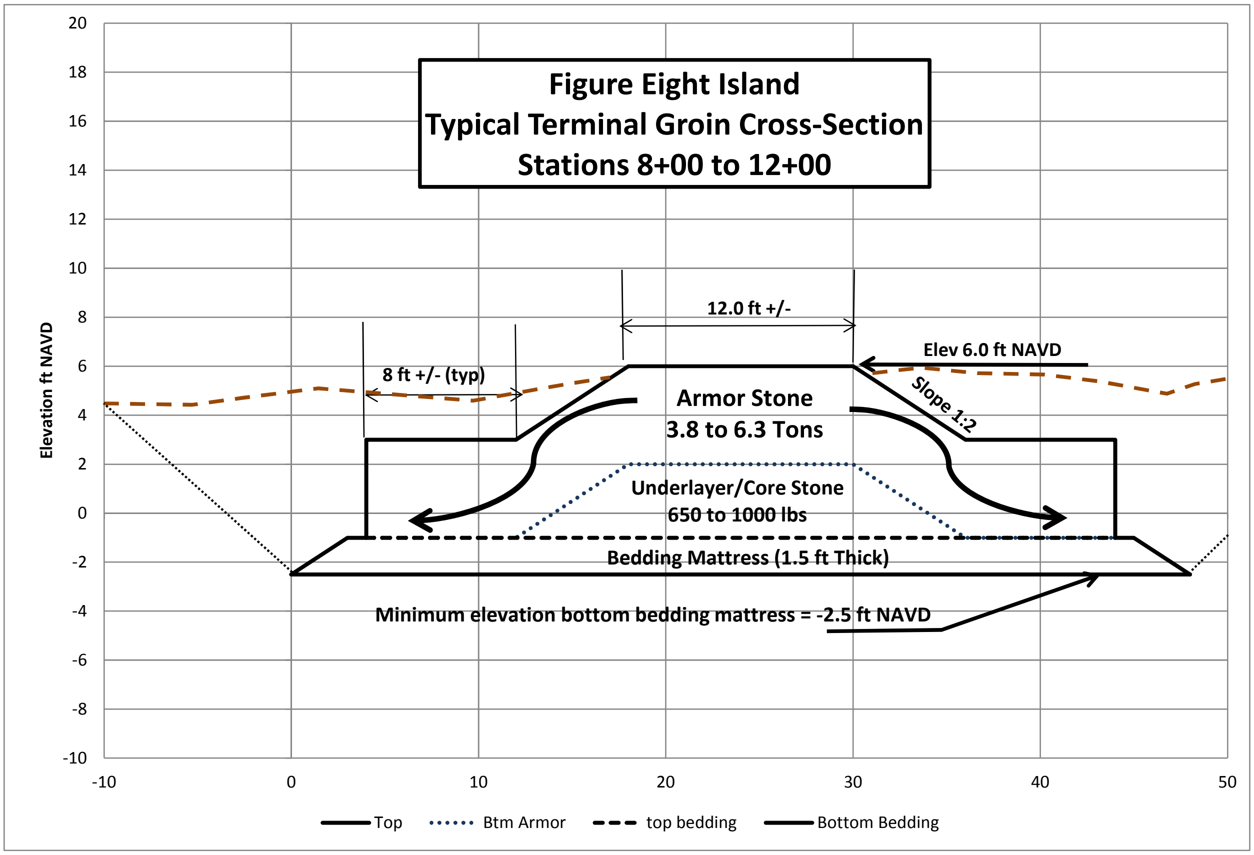



**FIGURE 9-17: Typical Terminal Groin Cross-Section 1.**

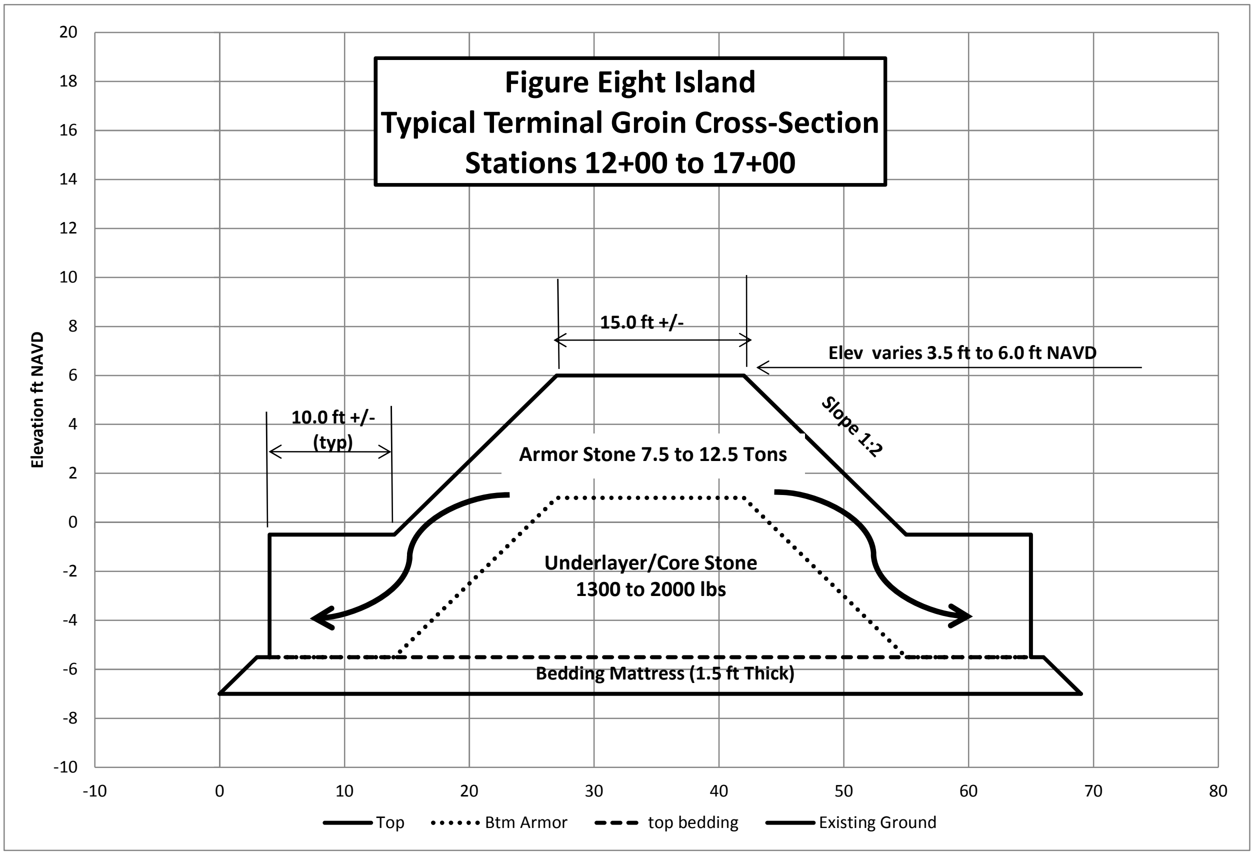



**FIGURE 9-18: Typical Terminal Groin Cross-Section 2.**

### 9.3.2 Groin Fillet

Based on the proposed length of the groin discussed above, if the terminal groin is not accompanied by beach fill, an accretion fillet would form south of the structure through the entrapment of northbound littoral sediment. The entrapment of the littoral material would eventually widen the beach on the order of 222 feet immediately next to the groin, with the fillet gradually merging with the exiting shoreline approximately 2,000 to 2,500 feet to the south. Fillet growth based on model results is detailed later in this report. The volume of littoral material required to create the fillet could range from 200,000 cubic yards to 315,000 cubic yards and, in the absence of artificial fill, could take 2 to 5 years to completely form. However, Alternative 5A includes the artificial creation of an accretion fillet and beach fill south to Bridge Road using material derived from dredging the portions of Nixon Channel shown in Figures 9-19 to 9-21. The artificial creation of the fillet combined with the groin's length, low crest elevation, and large voids between the stones would allow sediment transport to continue past the groin and into Rich Inlet by passing over, around, and/or through the terminal groin. The rate of sediment transport into Rich Inlet from Figure Eight Island with the groin could be at a somewhat reduced rate compared to exiting conditions. The reduced rate of transport into the inlet would be due to the elimination of the direct influence of tidal currents on sand transport off the extreme north end of the island and the realignment of the shoreline within the accretion fillet to that comparable to the shoreline farther south.

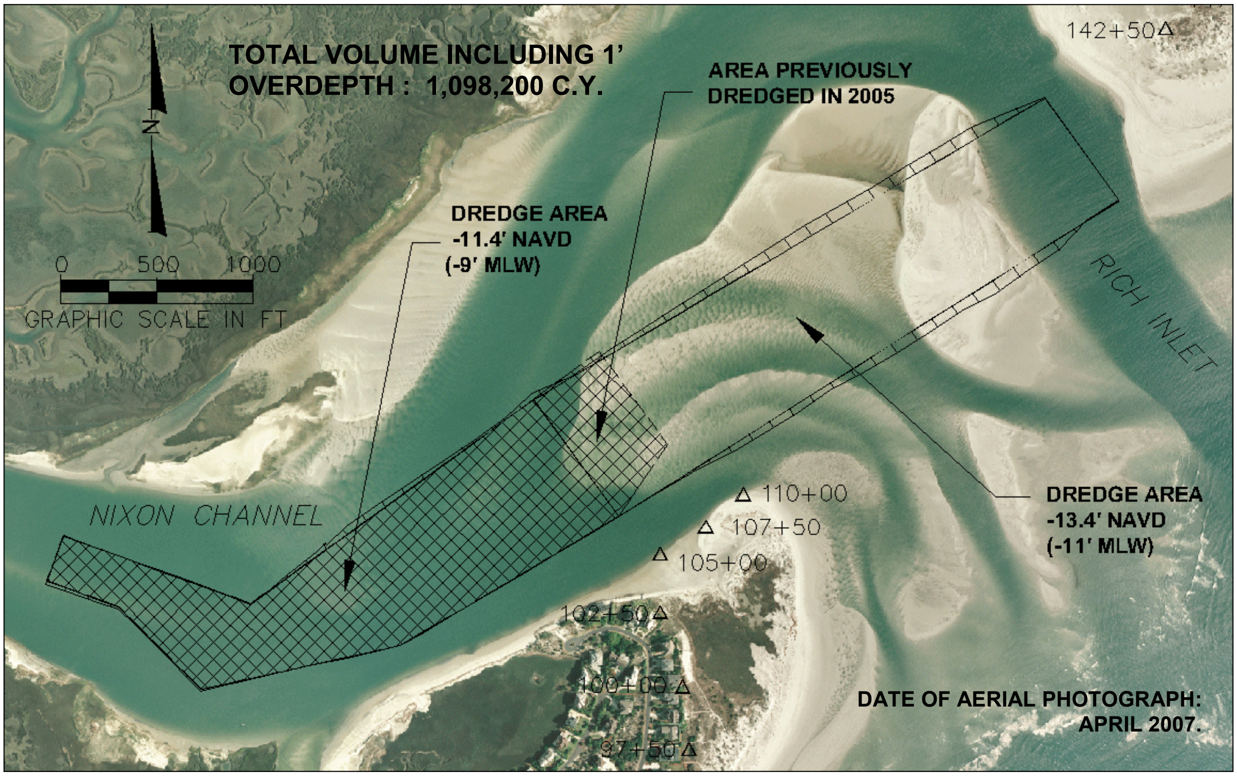



**FIGURE 9-19: Alternative 5A, Terminal Groin Dredging Option 1.**

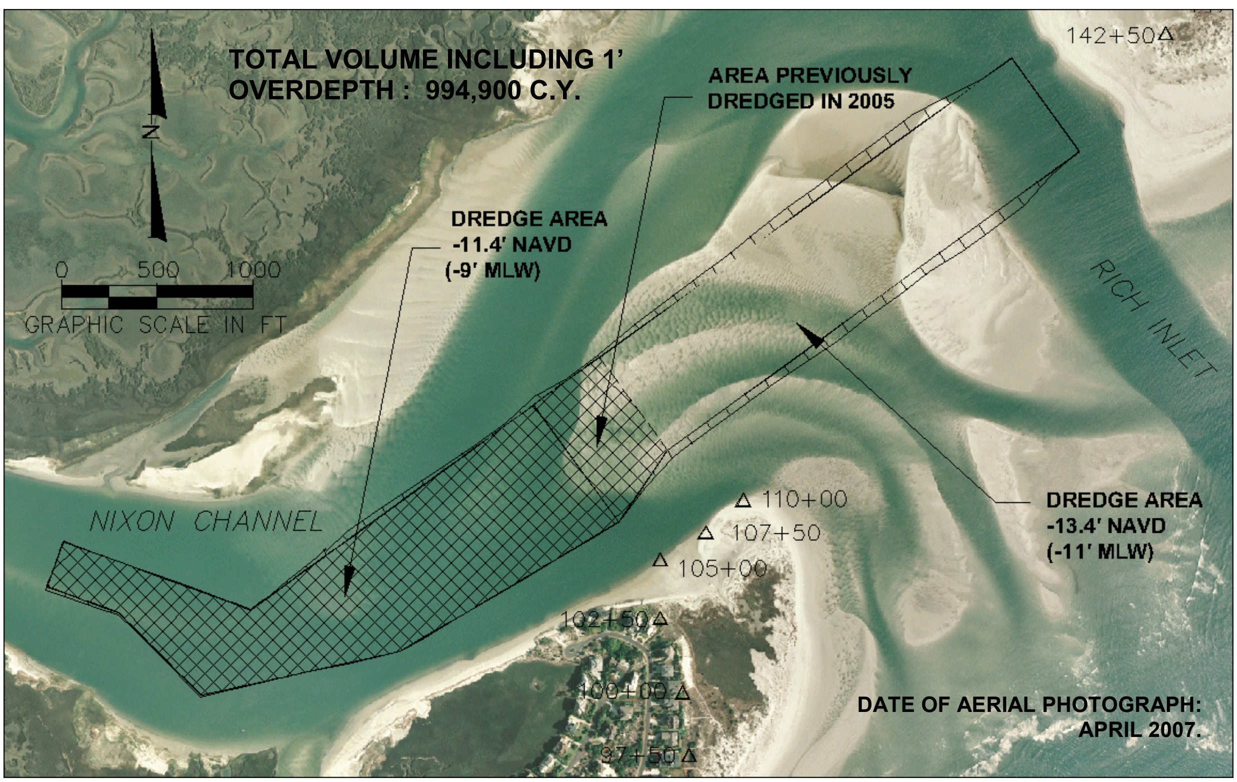



**FIGURE 9-20: Alternative 5A, Terminal Groin Dredging Option 2.**

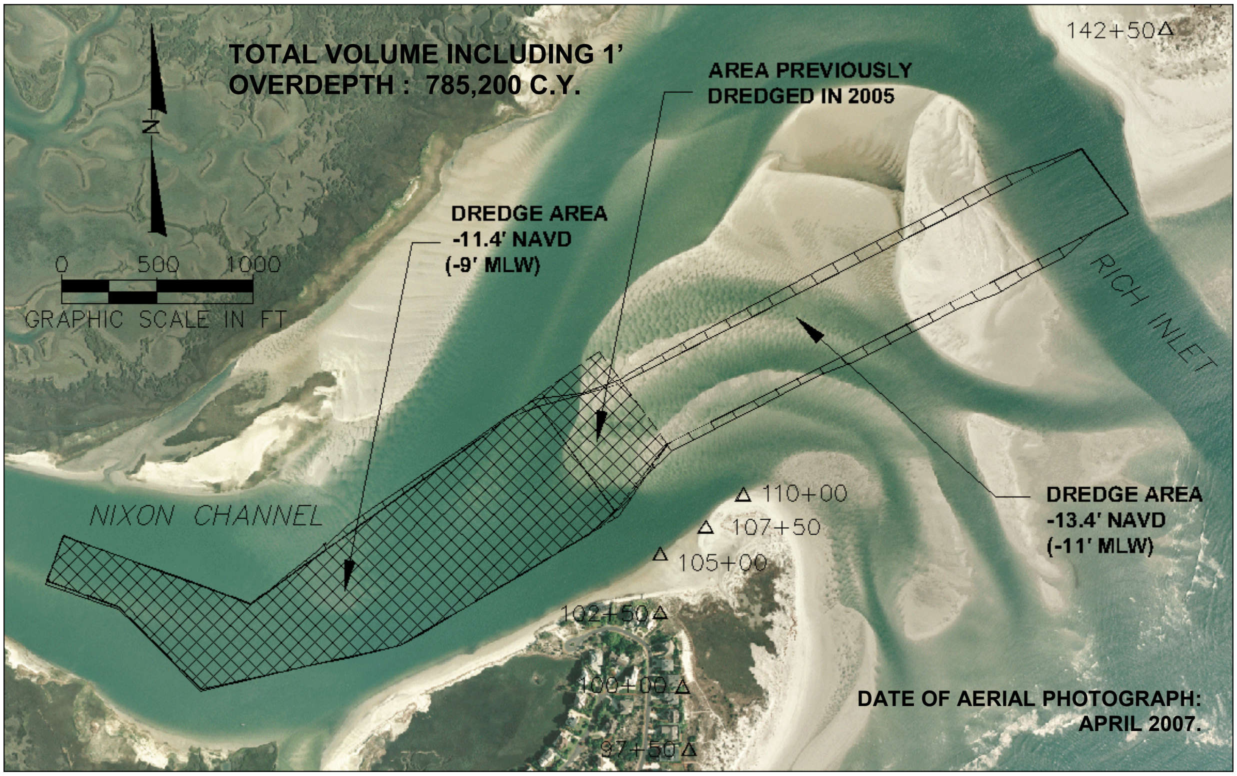


**FIGURE 9-21: Alternative 5A, Terminal Groin Dredging Option 3.**

### 9.2.3 Maintenance Dredging in Nixon Channel

Alternative 5A includes maintenance dredging in Nixon Channel. The area to be dredged includes all of the area that was last dredged in 2009 and 2011 (see Table 6-2), along with a connecting cut between the 2009 and 2011 dredging area and the existing entrance channel. The purposes of the connecting cut are to:

- Facilitate navigation between the existing entrance channel and Nixon Channel.

- Provide for a straight flow pattern through Nixon Channel to reduce the severity of erosion along the Nixon Channel shoreline at the end of N. Beach Road.

To meet these objectives, along with those in Section 2.0, three dredging options have been proposed for Alternative 5A:

- Option 1 – 660-740 foot wide connecting cut.
- Option 2 – 600 foot wide connecting cut.
- Option 3 – 395-416 foot wide connecting cut.

Plan views, cut depths, and volumes for each dredging option appear in Figures 9-19 to 9-21. Similar to Alternative 3, all side slopes are equal to 1 vertical on 5 horizontal. Inside the new connecting cut, the design cut depth is -13.4 feet NAVD (-11 feet MLW). Within the previously dredged area, the cut depth is equal to -13.4 feet NAVD along the easternmost 423 feet and -11.4 feet NAVD (-9 feet MLW) elsewhere.

The preferred dredging option for the terminal groin alternative is Dredging Option 2. Dredging Option 3 is the smallest of the dredging options in terms of both cost and impact. However, it has two disadvantages:

- The bottom width of the channel is relatively narrow, making the channel less conducive to navigation.

- Shoaling of the relatively small connecting channel would completely close the channel within one to two years.

Dredging Option 2 (Figure 9-20) provides a larger amount of fill material that can pre-fill the groin and provide reasonable nourishment of the beach south to Bridge Road. In addition, the channel is more conducive to navigation, with a depth of at least -10 feet NAVD being maintained at the seaward end of Nixon Channel over the 5-year maintenance cycle. Although Dredging Option 1 provides the most amount of fill material, it would not improve project performance and would be more expensive to construct. Overall, Dredging Option 2 represents the best balance of performance, cost, and impact. Accordingly, Dredging Option 2 is the preferred dredging option for the terminal groin Alternative 5A. Representative cross-sections appear in Figure 9-22.

### 9.3.4 Beach Fill Areas

Based on the most recent surveys and an allowable overdepth of one-foot, excavation of the dredge area in Figure 9-20 will provide 994,900 cubic yards of material for beach nourishment. Similar to Alternative 3, this solution features two fill areas – one fill area fronting Nixon Channel, and a second fill area along the oceanfront extending from Beachbay Lane (F90+00) to Rich Inlet.

Although the maintenance cycle of the project will be 5-years, a large volume is required to pre-fill the terminal groin and restore the September 1998 shoreline at the location of the groin. By straightening the shoreline immediately south of the terminal groin and reducing the direct impact of tidal currents along the extreme north end of the island, the terminal groin should reduce erosion rates at the island's northern end while allowing wave induced sediment transport to pass over, around, and/or through the terminal groin. Between profile 75+00 (south of Surf Court) and the terminal groin, fill distributions are based on the volume of material that would be placed to pre-fill the groin fillet. South of profile 75+00, fill distributions are based on 3 years of erosion, given the retreat rates in Tables 9-2 and 9-5, a berm elevation of +6 feet NAVD, a depth of closure equal to -24 feet NAVD, and an overfill factor of 1.044 (Table 9-1). It should be noted that the 3 year assumption is simply used as a means of apportioning the fill within the available volume discussed above. Based on the model results discussed later in the report, the amount of fill south of Surf Court should be sufficient for preventing erosion into the present shoreline over a 5 year period.

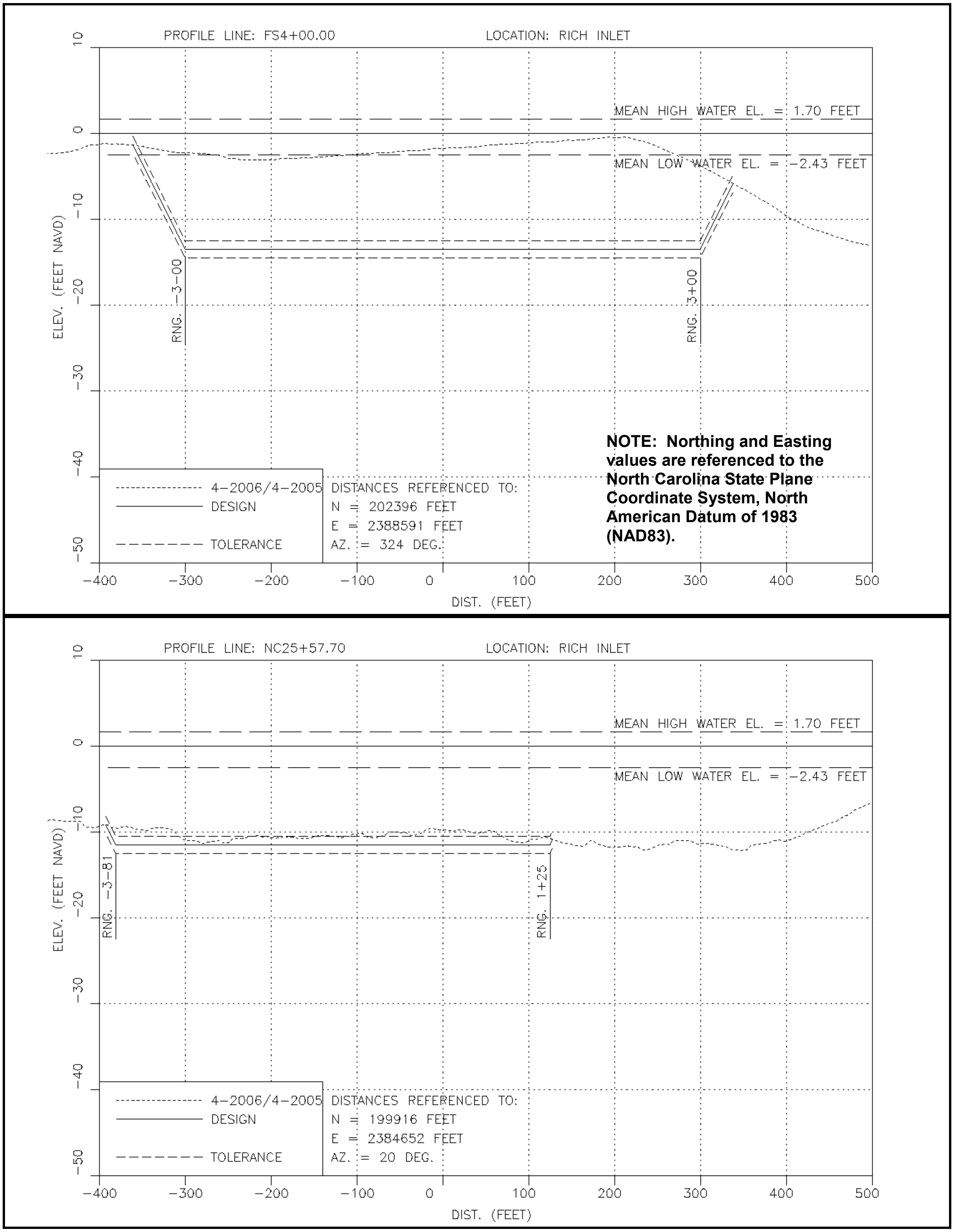



**FIGURE 9-22: Representative Dredging Cross-Sections, Preferred Dredging Option (2), Alternative 5A.**

## TABLE 9-6

## OCEANFRONT BEACH DISPOSAL AREA
## ALTERNATIVE 5A
## FIGURE EIGHT ISLAND / RICH INLET, NC

| Profile Line | Fill Length (feet) | Retreat Rate (feet/year) | Fill Distribution (c.y./foot) Beach | Dune | Total | Fill Volume (cubic yards) Beach | Dune | Total |
|---|---|---|---|---|---|---|---|---|
| F90+00 | | -9.2 | 0.0 | | 0.0 | | | |
| | 1,000 | | | | | 16,100 | | 16,100 |
| F100+00 | | -9.2 | 32.1 | | 32.1 | | | |
| | 1,001 | | | | | 32,200 | | 32,200 |
| 0+00 | | -9.2 | 32.1 | | 32.1 | | | |
| | 1,000 | | | | | 32,100 | | 32,100 |
| 10+00 | | -9.2 | 32.1 | | 32.1 | | | |
| | 1,000 | | | | | 32,100 | | 32,100 |
| 20+00 | | -9.2 | 32.1 | | 32.1 | | | |
| | 1,000 | | | | | 32,100 | | 32,100 |
| 30+00 | | -9.2 | 32.1 | | 32.1 | | | |
| | 1,000 | | | | | 32,100 | | 32,100 |
| 40+00 | | -9.2 | 32.1 | | 32.1 | | | |
| | 1,000 | | | | | 59,100 | | 59,100 |
| 50+00 | | -24.8 | 86.1 | | 86.1 | | | |
| | 1,000 | | | | | 86,100 | | 86,100 |
| 60+00 | | -24.8 | 86.1 | | 86.1 | | | |
| | 1,000 | | | | | 86,100 | | 86,100 |
| 70+00 | | -24.8 | 86.1 | | 86.1 | | | |
| | 250 | | | | | 21,500 | | 21,500 |
| 72+50 | | -24.8 | 86.1 | | 86.1 | | | |
| | 250 | | | | | 21,500 | | 21,500 |
| 75+00 | | -24.8 | 86.1 | | 86.1 | | | |
| | 250 | | | | | 24,500 | | 24,500 |
| 77+50 | | -24.8 | 109.6 | 8.7 | 118.3 | | | |
| | 250 | | | | | 30,300 | 3,300 | 33,600 |
| 80+00 | | -24.8 | 133.0 | 17.4 | 150.4 | | | |
| | 250 | | | | | 36,200 | 4,100 | 40,300 |
| 82+50 | | -24.8 | 156.5 | 15.1 | 171.6 | | | |
| | 250 | | | | | 42,000 | 3,500 | 45,500 |
| 85+00 | | -24.8 | 179.9 | 12.8 | 192.7 | | | |
| | 250 | | | | | 47,900 | 3,700 | 51,600 |
| 87+50 | | -24.8 | 203.3 | 17.0 | 220.3 | | | |
| | 250 | | | | | 53,800 | 4,800 | 58,600 |
| 90+00 | | -24.8 | 226.8 | 21.2 | 248.0 | | | |
| | 250 | | | | | 59,600 | 4,600 | 64,200 |
| 92+50 | | -24.8 | 250.2 | 15.8 | 266.1 | | | |
| | 250 | | | | | 65,500 | 3,300 | 68,800 |
| 95+00 | | -24.8 | 273.6 | 10.5 | 284.1 | | | |
| | 250 | | | | | 54,100 | | 54,100 |
| 97+50 | | -24.8 | 158.8 | | 158.8 | | | |
| | 250 | | | | | 20,800 | | 20,800 |
| 100+00 | | -24.8 | 7.9 | | 7.9 | | | |
| TOTAL | 12,001 | | 73.8 | 15.6 | 76.1 | 885,700 | 27,300 | 913,000 |

**TABLE 9-7**

**NIXON DISPOSAL AREA**
**ALTERNATIVE 5A**
**FIGURE EIGHT ISLAND / RICH INLET, NC**

| Profile Line | Fill Length (feet) | Beach Fill Distribution (c.y./foot) | Beach Fill Volume (c.y.) |
|---|---|---|---|
| FS26+00.00 | | 0.7 | |
| | 50 | | 100 |
| NC0+00.00 | | 2.9 | |
| | 200 | | 3,000 |
| NC2+00.00 | | 27.3 | |
| | 200 | | 7,400 |
| NC4+00.00 | | 46.5 | |
| | 23 | | 1,100 |
| NC4+22.86 | | 46.5 | |
| | 177 | | 8,800 |
| NC6+00.00 | | 53.3 | |
| | 200 | | 10,600 |
| NC8+00.00 | | 53.0 | |
| | 200 | | 10,400 |
| NC10+00.00 | | 50.5 | |
| | 200 | | 10,000 |
| NC12+00.00 | | 49.3 | |
| | 200 | | 8,100 |
| NC14+00.00 | | 31.5 | |
| | 200 | | 4,400 |
| NC16+00.00 | | 12.8 | |
| | 137 | | 1,100 |
| NC17+37.21 | | 2.7 | |
| TOTAL | 1,787 | 36.4 | 65,000 |

The fill area along the Nixon Channel shoreline contains 65,000 cubic yards, similar to Alternative 3.

### 9.3.5 Profile Shape

Profile shapes along the fill area are based on the same assumptions as those of Alternative 3. Representative cross-sections appear in Figures 9-23 through 9-24.

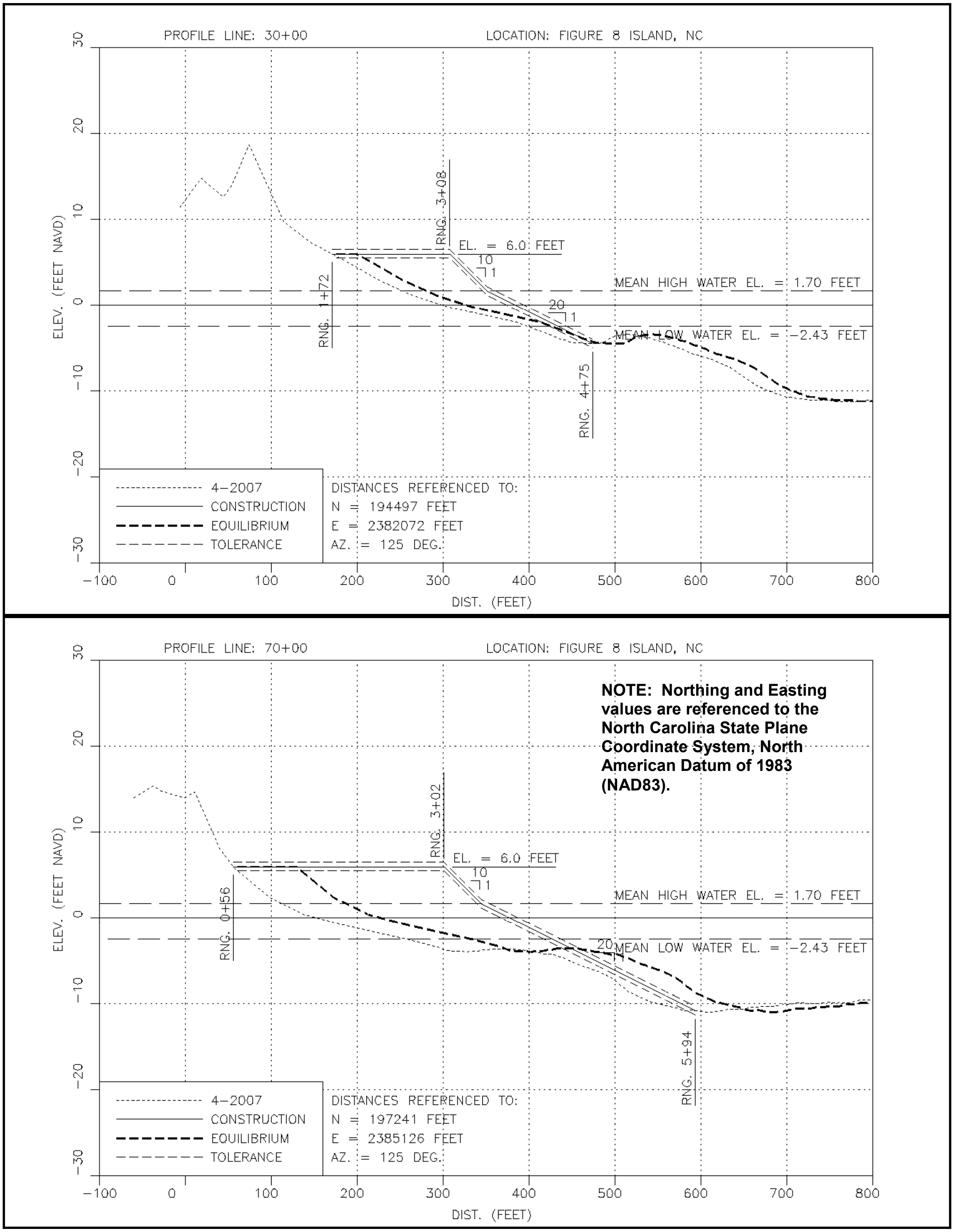
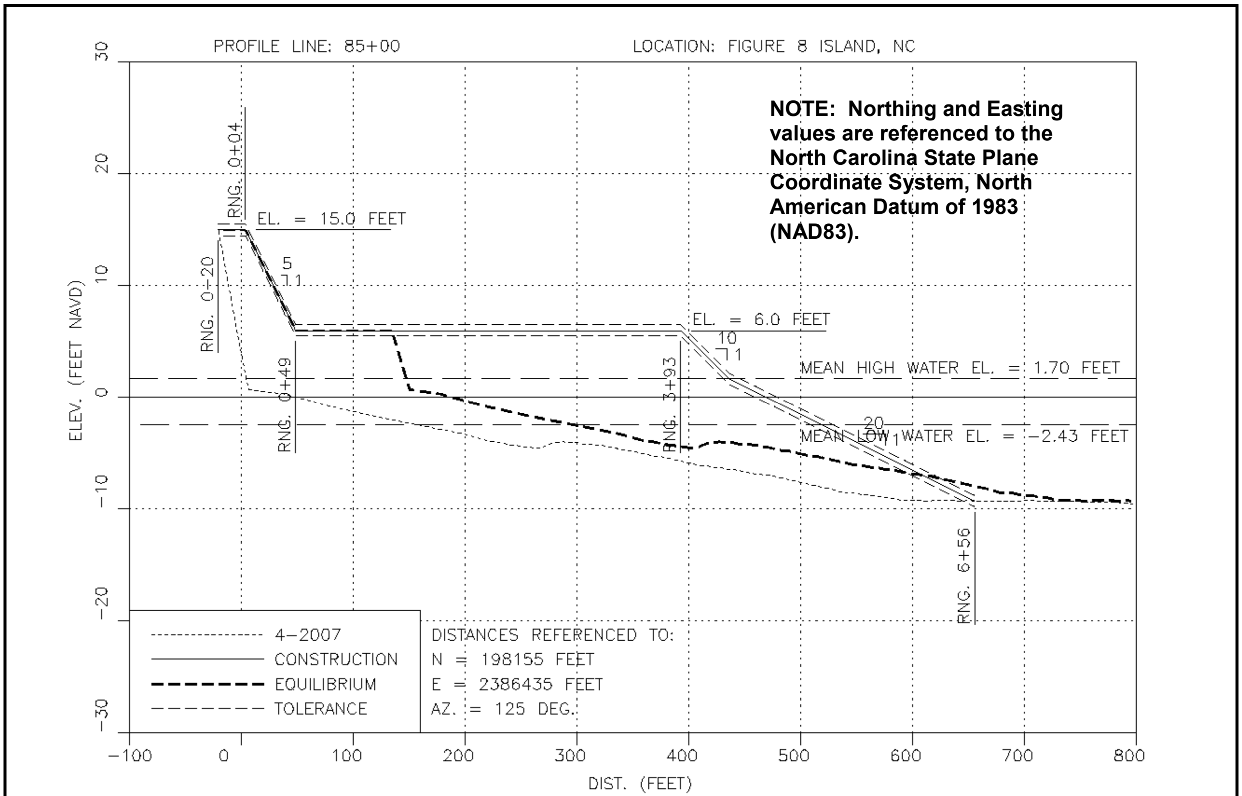



**FIGURE 9-23: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 5A.**



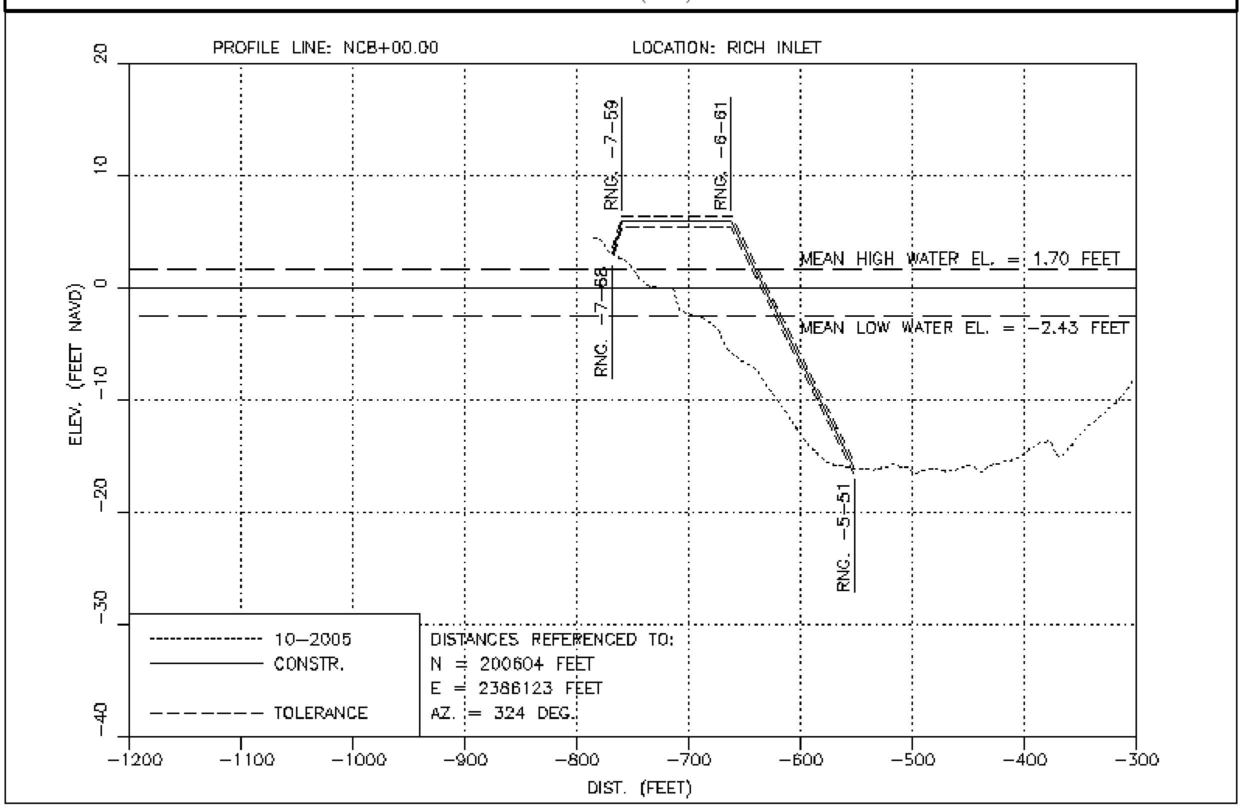




**FIGURE 9-24: Representative Cross-Sections along the North End of Figure Eight Island, Alternative 5A.**

### 9.2.6 Design Summary for Alternative 5A

Based on the various features discussed above, the dredging and groin option for Alternative 5A can be summarized by the following:

- Terminal groin length = 700 feet from the April 2007 shoreline, 1,600 feet total.

- Terminal groin footprint (bottom surface area) = 1.1 acres.

- Groin crest elevation:
  - Landward segment (700 feet): +4 feet NAVD.
  - Main segment (800 feet): +6 feet NAVD.
  - Sloping segment near construction shoreline (37 feet): +3.5 to +6 feet NAVD.
  - Most seaward segment (163 feet): +3.5 feet NAVD.

- Groin material: Sheet Pile (concrete or steel) and Granite quarry stone. Armor stone ranging from 3.8 tons on landward end to 12.5 tons on seaward end.

- Dredge cut depth:
  - East section of dredge cut: -13.43 feet (-11 feet MLW) + 1 foot overdepth.
  - West section of dredge cut: -11.43 feet (-9 feet MLW) + 1 foot overdepth.

- Dredged cut bottom width:
  - East end of dredge cut: 600 feet.
  - Bending section of dredge cut: 250 to 754 feet.
  - West end of dredge cut: 250 feet.

- Dredge cut length: 6,156 feet.

- Dredge Volume = 864,800 c.y. + 130,100 c.y. overdepth based on the April/October 2005 surveys = 994,900 c.y. total.

- Oceanfront Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.
  - Side Slopes:
    - 1 vertical on 5 horizontal in the dune fill area
    - 1 vertical on 10 horizontal above mean high water (+1.7' NAVD)
    - 1 vertical on 20 horizontal (assumed) below mean high water
  - Fill Length = 12,000 feet (Station F90+00 to 100+00).
  - Volume = 913,000 c.y. + 15,700 c.y. tolerance based on April 2007 survey = 928,700 c.y. total.

- Nixon Disposal Area:
  - Berm Elevation = +6 feet NAVD + 0.5 foot tolerance.
  - Construction Berm Width = varies.

- Side Slopes:
    - 1 vertical on 5 horizontal
- Fill Length = 1,787 feet.
- Volume = 65,000 c.y. + 1,200 c.y. tolerance based on April/October 2005 surveys = 66,200 c.y. total.

A plan view of Alternative 5A as whole appears in Figures 9-25 and 9-26.


**FIGURE 9-25: Alternative 5A Dredging and Groin Option and Beach Fill Layout.**

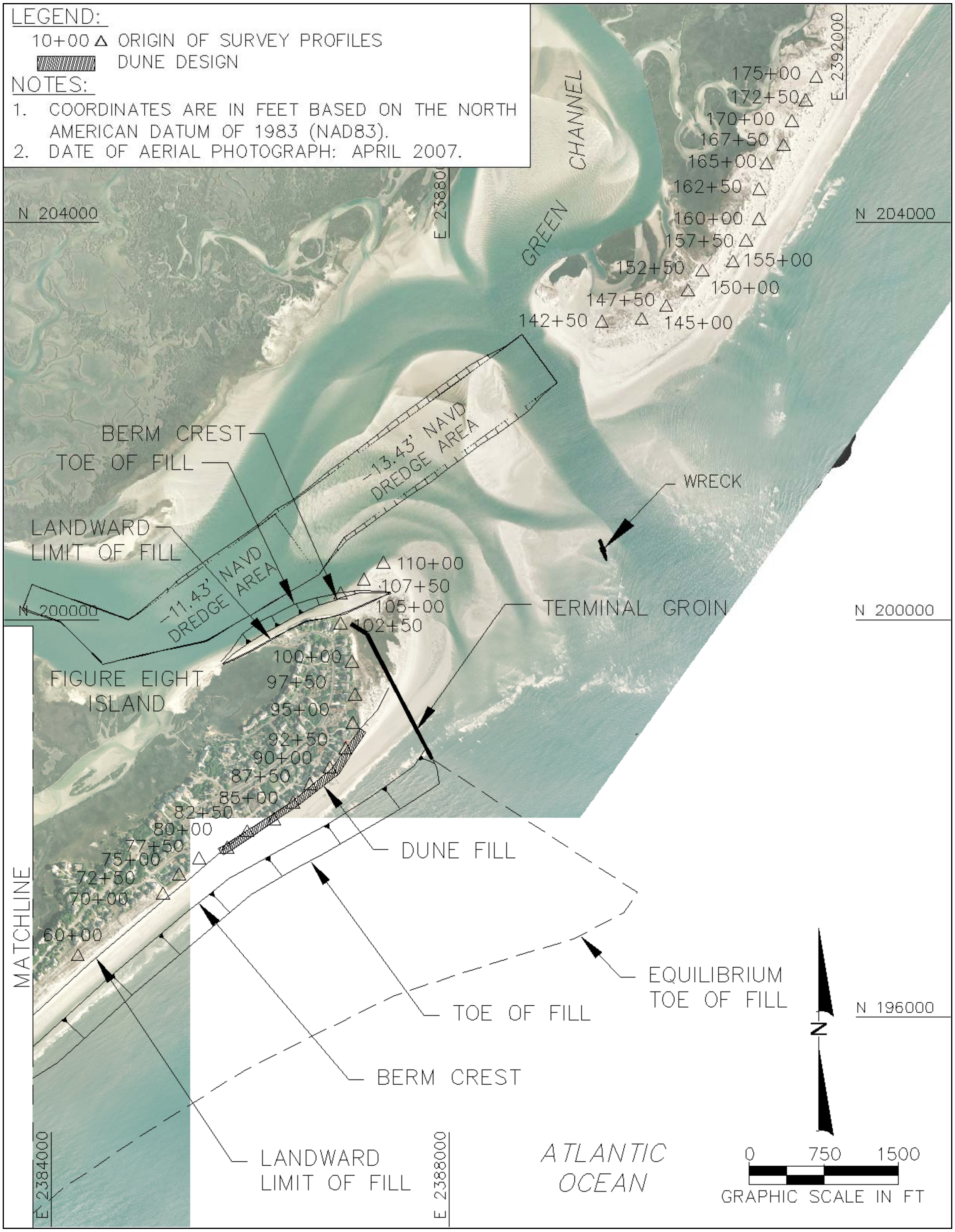



**FIGURE 9-26: Alternative 5A Dredging and Groin Option and Beach Fill Layout.**

## 9.4 Alternative 5B – Terminal Groin with Beach Fill from Other Sources

The terminal groin would have the same design as that described for Alternative 5A as would the beach fill along Nixon Channel. With regard to the beach fill along the ocean shoreline, analysis of the Delft3D model results for Alternative 5A indicated the initial beach fill was excessive, particularly along the segment of the beach south of station 80+00. Again, the beach fill design associated with Alternative 5A was based on the optimal utilization of the material removed to construct the new channel connector from the inlet gorge into Nixon Channel not on the beach fill volume needed to offset shoreline erosion tendencies. Since Alternative 5B does not include the excavation of a new connector channel into Nixon Channel, the beach fill for Alternative 5B was designed to address erosion protection needs.

The design of the beach fill for Alternative 5B, which is discussed in Chapter 5, was based on the Delft3D simulated behavior of the Figure Eight Island shoreline in response to the installation of a terminal groin without any accompanying beach fill and the need to prefill the beach immediately south of the terminal groin. The results of the terminal groin simulation without beach fill indicated the area south of station 60+00 to station 30+00 would experience very moderate erosion which would not pose any immediate threat to upland development. The shoreline segment from station 30+00 to station F90+00 accreted and would not need any initial beach fill. Based on this result and the modeled rate of beach fill retention under Alternative 5A, the beach fill for Alternative 5B would be limited to the area north of station 60+00 and would have the placement rates and design berm widths shown in Table 9.8. Even though the area south of station 60+00 to station F90+00 would not receive any initial nourishment, this area would be included in the project monitoring plan, presented in Chapter 6, with nourishment provided on an as-needed basis or in response to shoreline changes exceeding the shoreline change thresholds also discussed in Chapter 6.

**Table 9.8 Alternative 5B beach fill placement volumes and design berm widths.**

| Shoreline Segment (Baseline Stations) | Placement Volume (cy/lf) | Design Berm Width (ft) |
|---|---|---|
| 100+00 to 80+00 | 80 | 69 |
| 80+00 to 72+50 (transition) | 80 to 20 | 69 to 17 |
| 72+50 to 70+00 | 20 | 17 |
| 70+00 to 60+00 (transition) | 20 to 0 | 17 to 0 |

The beach fill would be constructed to an elevation of 1.8 m (6.0 ft) NAVD and would include an artificial dune similar to Alternatives 3, 4, and 5A between stations 77+50 and 95+00. A plan layout for Alternative 5B is provided in Figure 9-27. Typical profiles of the ocean shoreline beach fill for Alternative 5B are provided in Figures 9-28 and 9-29. Beach fill profiles for the Nixon Channel are the same as shown under Alternative 3. The total volume of beach fill along the ocean shoreline, including the dune fill, would be 224,800 cubic yards as shown in Table 9.9. The Nixon Channel beach fill would require 65,000 cubic yards bringing the total beach fill volume to 289,800 cubic yards.

Material to construct the beach fill for Alternative 5B would be derived from maintenance of the existing permit area in Nixon Channel. Based on past maintenance operations in the existing permit area of Nixon Channel and anticipated shoaling rates indicated by the Delft3D simulations for the other alternatives, the volume of material available from the existing permit area would satisfy the volumetric requirements for Alternative 5B. The beach compatible material contained in the three northern upland disposal areas situated adjacent to the AIWW (discussed under Alternative 4) would serve as contingency sediment sources in the event shoaling of the Nixon Channel permit area is not sufficient to satisfy periodic beach nourishment needs or Figure Eight needs additional material to respond to storm damage.

Construction of the beach fill could be accomplished with a 16-inch to 18-inch cutter-suction pipeline dredge which are similar to the ones that perform routine maintenance in the AIWW.

**TABLE 9-9**

**OCEANFRONT BEACH DISPOSAL AREA**
**ALTERNATIVE 5B**
**FIGURE EIGHT ISLAND / RICH INLET, NC**

| Profile Line | Fill Length (feet) | Fill Distribution CY/LF | Fill Volume CY | Dune Volume CY | Total Volume CY |
|---|---|---|---|---|---|
| 60+00 | 0 | 0 | 0 | | 0 |
| 70+00 | 1,000 | 20 | 10,000 | | 10,000 |
| 72+50 | 250 | 20 | 5,000 | | 5,000 |
| 75+00 | 250 | 20 | 5,000 | | 5,000 |
| 77+50 | 250 | 20 | 5,000 | | 5,000 |
| 80+00 | 250 | 80 | 12,500 | 3,300 | 15,800 |
| 82+50 | 250 | 80 | 20,000 | 4,100 | 24,100 |
| 85+00 | 250 | 80 | 20,000 | 3,500 | 23,500 |
| 87+50 | 250 | 80 | 20,000 | 3,700 | 23,700 |
| 90+00 | 250 | 80 | 20,000 | 4,800 | 24,800 |
| 92+50 | 250 | 80 | 20,000 | 4,600 | 24,600 |
| 95+00 | 250 | 80 | 20,000 | 3,300 | 23,300 |
| 97+50 | 250 | 80 | 20,000 | | 20,000 |
| 100+00 | 250 | 80 | 20,000 | | 20,000 |
| TOTAL | 12,000 | | 197,500 | 27,300 | 224,800 |

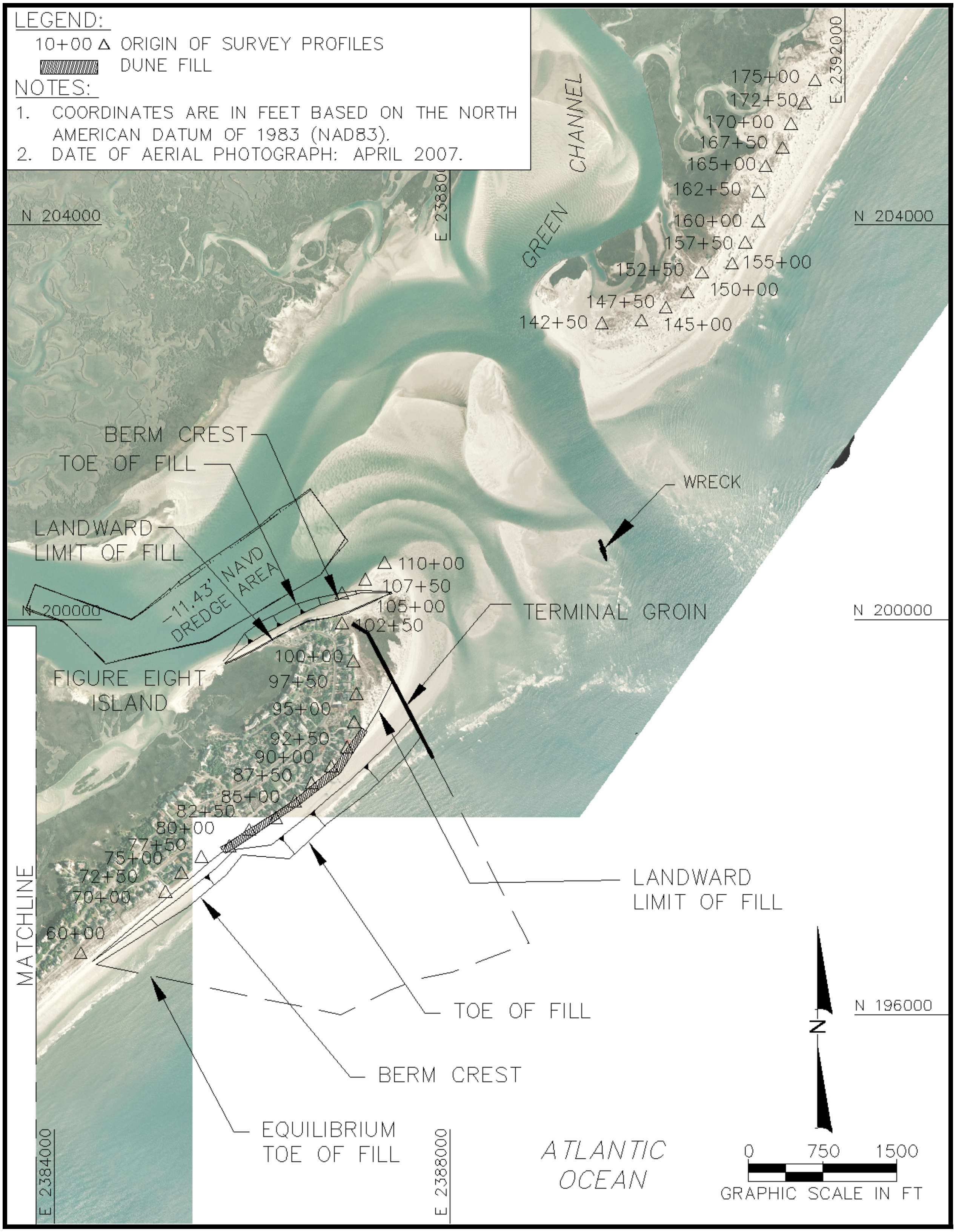
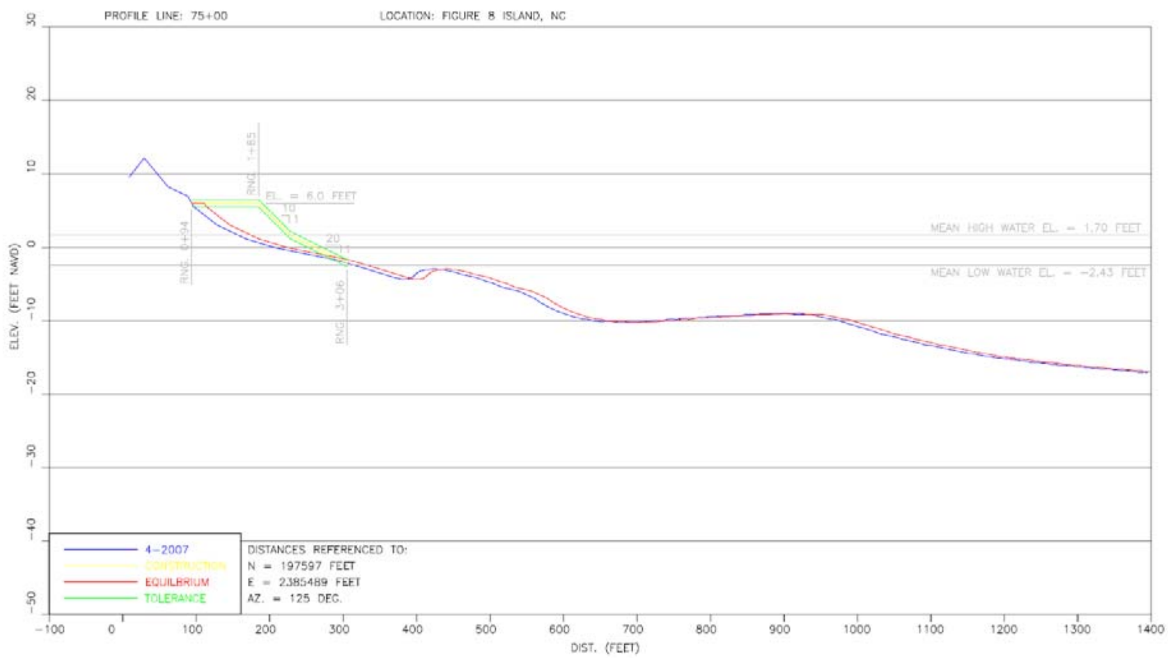



**FIGURE 9-27: Alternative 5B Dredging and Groin Option and Beach Fill Layout.**



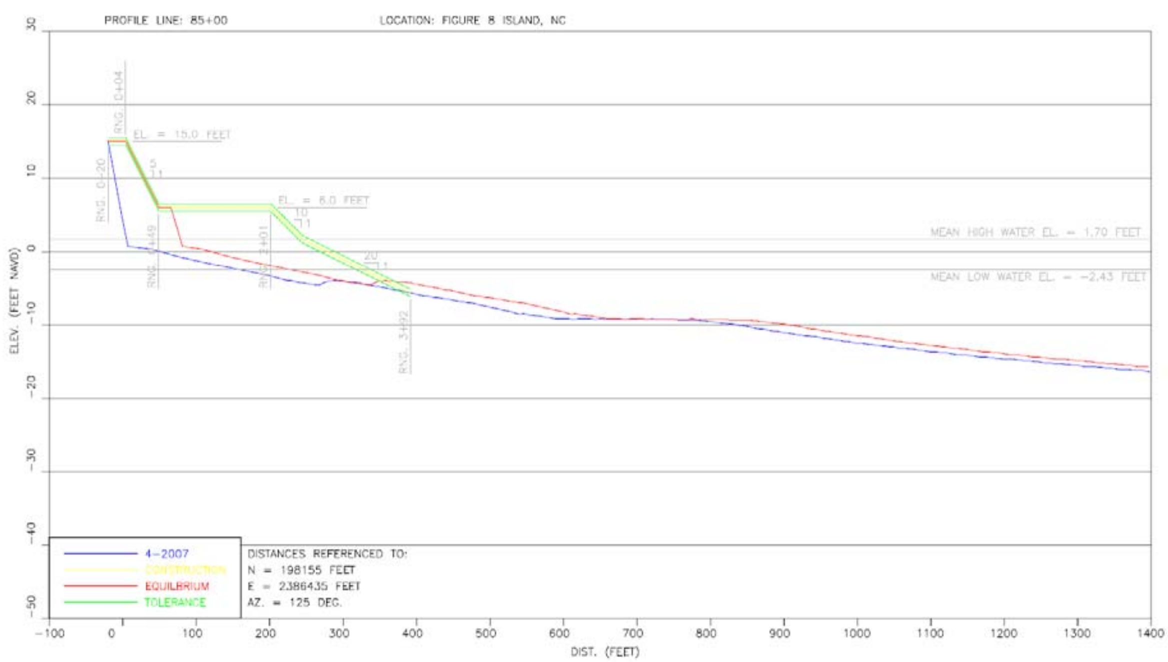
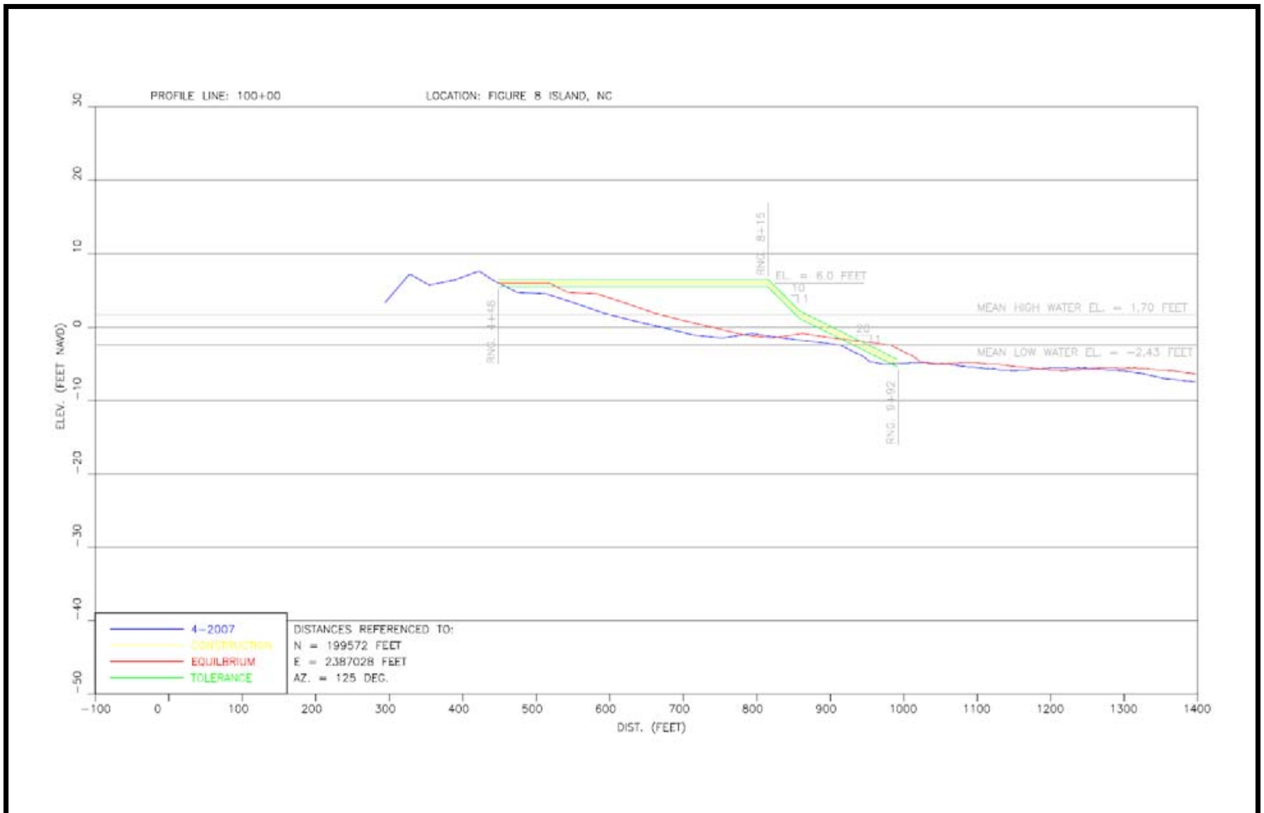




**FIGURE 9-28: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 5B.**



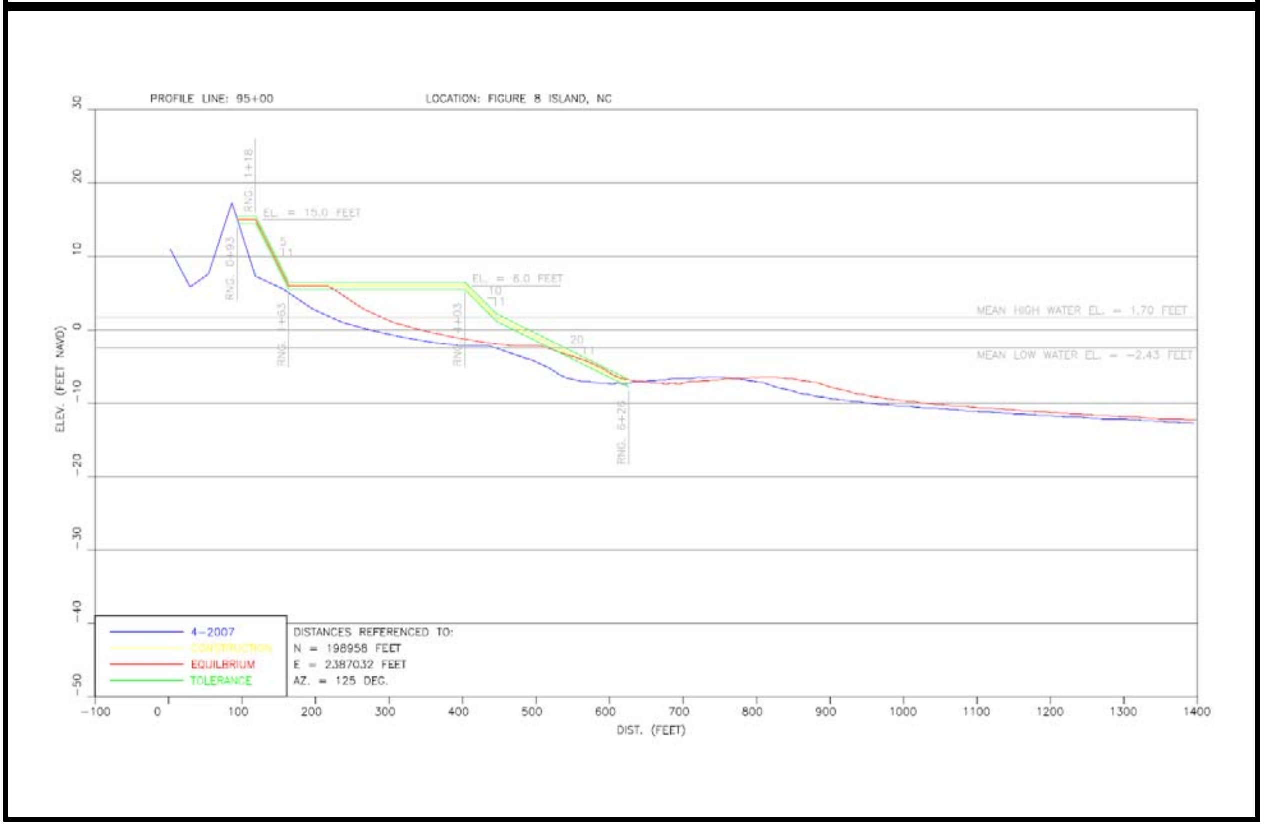




**FIGURE 9-29: Representative Cross-Sections along the Oceanfront Beach Fill Area, Alternative 5B.**

## 10.0 PROJECT PERFORMANCE DURING STORMS – SBEACH MODEL STUDY

Beach erosion and shoreline recession occurs during severe storm events, partially as a result of cross-shore sediment transport processes. Storm erosion along the project area was evaluated using the Storm Induced Beach Change Model (SBEACH, Larson and Kraus, 1989).

The 2nd goal of the Figure Eight Island Beach Nourishment Project (Section 2.0) is to protect upland property. To evaluate economic damages to upland property, storm erosion during a set of historic storms was simulated using the SBEACH model.

### 10.1 SBEACH Model Background

SBEACH simulates beach profile changes that result from varying storm waves and water levels. These profile changes include the formation and cross-shore movement of morphological features such as longshore bars, troughs, berms, and dunes. SBEACH is a one-dimensional model that assumes that the simulated profile changes are produced only by cross-shore processes. Longshore sediment transport processes are neglected.

SBEACH is an empirically based numerical model, formulated using both field data and the results of large-scale physical model tests. Input data required by SBEACH includes the beach and offshore cross-section, the median sediment grain size, several calibration parameters, and the time histories of the waves, winds, and water elevations. SBEACH calculates the cross-shore variation in wave height and wave setup at discrete points along the profile from the offshore zone to the landward survey limit. The following basic assumptions underlie the SBEACH model:

- Breaking waves and variations in water level are the major causes of sand transport and profile change.
- The median sediment grain diameter on the profile is reasonably uniform across shore.
- Cross-shore sand transport takes place primarily in the surf zone.
- The influence of structures blocking longshore transport is small, and the shoreline is straight (i.e., longshore effects are negligible during the term of simulation).
- Conservation of mass dictates that the amount of material eroded must equal the amount deposited.
- Linear wave theory is applicable everywhere along the beach profile.

Finally, this study assumes that the existing sandbags along Comber Road and Inlet Hook Road (profiles 77+50 to 95+00) offer negligible protection against storm erosion.

## 10.2 Calibration

Calibration of the SBEACH model was based on Hurricane Ophelia, which passed 30 miles southeast of the project area in September 2005. Observed, directional wave data during the storm was taken from the NOAA Buoy 41035, Onslow Bay, North Carolina (34.48° N 77.28° W, see Figure 4-3 of main report). The water depth at this buoy was -32.4 feet NAVD. The maximum recorded significant wave height during the storm was 19 feet at this location. The maximum recorded wave period during the storm was 11 seconds. The average, observed water temperature during the storm was 87°F.

Water levels and wind velocities for the model calibration were based on the measurements at NOAA tidal benchmark 8658163 (34°12.6'N, 77°47.7'W) in Wrightsville Beach, North Carolina. The water levels included the observed storm surge for this area. The storm surge was calculated to be the difference between the observed water level and the astronomical water level. Water levels and waves during the 171 hour event appear in Figure 10-1.

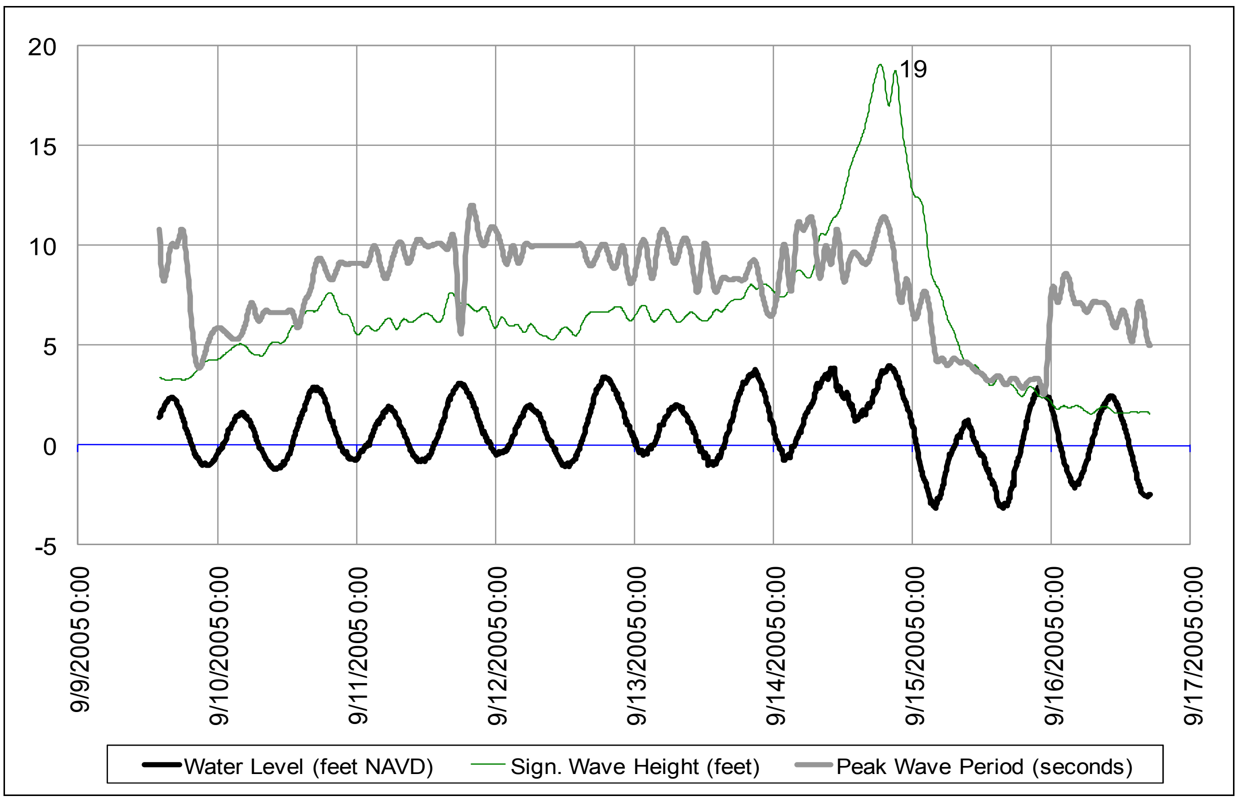



**FIGURE 10-1: Hurricane Ophelia, September 2005, Storm Conditions**

Pre-storm and post-storm beach profile surveys for this storm were surveyed by Gahagan & Bryant Associates, Inc. in April and October of 2005. Four profiles were modeled calibration: 20+00, 70+00, 80+00, 100+00, and 170+00. To calibrate the model, the SBEACH input parameters were varied in an iterative process until the model output resembled the October 2005 beach survey. Both the volume and post-storm profile shape above the mean high water line (MHW, +1.7' NAVD) and were the focus of the calibration.

Calibration of the model was based on the volume of material eroded above the MHW line. Seven (7) model runs were conducted on profiles 20+00, 70+00, 80+00, 100+00, and 170+00 using a range of values for the parameters described below. Each combination of K, $\varepsilon$, and $\lambda$ produced varied results for each profile in terms of the simulated eroded volume change matching the observed volume change. In calibrating the model for the study area, the following parameters were selected to produce the best match between the model output and the April 2005 survey profiles, and between the simulated and observed erosion volumes:

- The transport rate coefficient, $K = 7.91 \times 10^7$ $m^4/N$, is equal to the ratio between the cross-shore transport rate and the wave energy dissipation rate.

- The slope dependent coefficient, $\varepsilon = 0.005$ $m^2/s$, governs the influence of the profile slope on the cross-shore transport.

- The transport rate decay coefficient, $\lambda = 0.3$ $feet^{-1}$ governs the reduction in the wave height over the beach profile due to wave breaking.

- A landward surf zone depth of 0.5 feet, which is equal to the depth where the swash zone begins.

- A maximum slope angle prior to avalanching of 30˚.

- A water temperature of 87˚F, which determines the fall speed of the sediment.

To approximate the slope of the native beach at each profile, Dean's A factor curves ($Y=AX^{2/3}$) for various grain sizes (USACE, 2000, pp. III-3-22) were fitted to each April 2005 beach profile. Dean's A factor was calculated separately for each profile using the following equation:

$$A = \Sigma(Y) / \Sigma(X^{2/3})$$

where A = Dean's A-Factor
Y = MHW (1.7 feet NAVD) – Elevation of each survey point
X = Range of each survey point – MHW Range for each profile

The calculated A-Factors are listed in Table 10-1. The A-Factors for each profile were used in the calibration and modeling process.

The observed and simulated volume changes above MHW (+1.7 feet, NAVD) are displayed in Table 10-2 below. The MHW shoreline retreat was also estimated from the observed and simulated post-storm profiles. Negative volume and shoreline changes indicate erosion and retreat. Example calibration cross-sections for profile lines 20+00 and 70+00 appear in Figure 10-2.

**TABLE 10-1**

**DEAN'S A FACTOR**

| Profile | Dean's A Factor ($feet^{1/3}$) |
|---|---|
| 20+00 | 0.197 |
| 70+00 | 0.164 |
| 80+00 | 0.144 |
| 100+00 | 0.109 |
| 170+00 | 0.157 |

**TABLE 10-2**

**SBEACH CALIBRATION**
**HURRICANE OPHELIA (SEP. 2005)**
**FIGURE 8 ISLAND & RICH INLET, NC**

| Profile | Type | MHW Change (feet) | Volume Change above MHW (c.y./foot) |
|---|---|---|---|
| | OBSERVED CHANGES | | |
| 20+00 | Wide Downdrift Beach | -16.9 | -6.6 |
| 70+00 | Moderately Eroded Beach | -12.5 | -12.3 |
| 80+00 | Highly Eroded Beach | 4.7 | -4.7 |
| 100+00 | Wide Beach Near Inlet | -22.6 | 0.1 |
| 170+00 | Lea Hutaff Island | 64.0 | 4.7 |
| | Average - Figure 8 Island | -11.8 | -5.9 |
| | Average - All Profiles | 3.3 | -3.8 |
| | SIMULATED CHANGES | | |
| 20+00 | Wide Downdrift Beach | -18.9 | -6.6 |
| 70+00 | Moderately Eroded Beach | 5.5 | -9.6 |
| 80+00 | Highly Eroded Beach | -2.9 | -17.2 |
| 100+00 | Wide Beach Near Inlet | -37.2 | -4.5 |
| 170+00 | Lea Hutaff Island | -35.0 | -6.4 |
| | Average - Figure 8 Island | -13.4 | -9.5 |
| | Average - All Profiles | -17.7 | -8.9 |

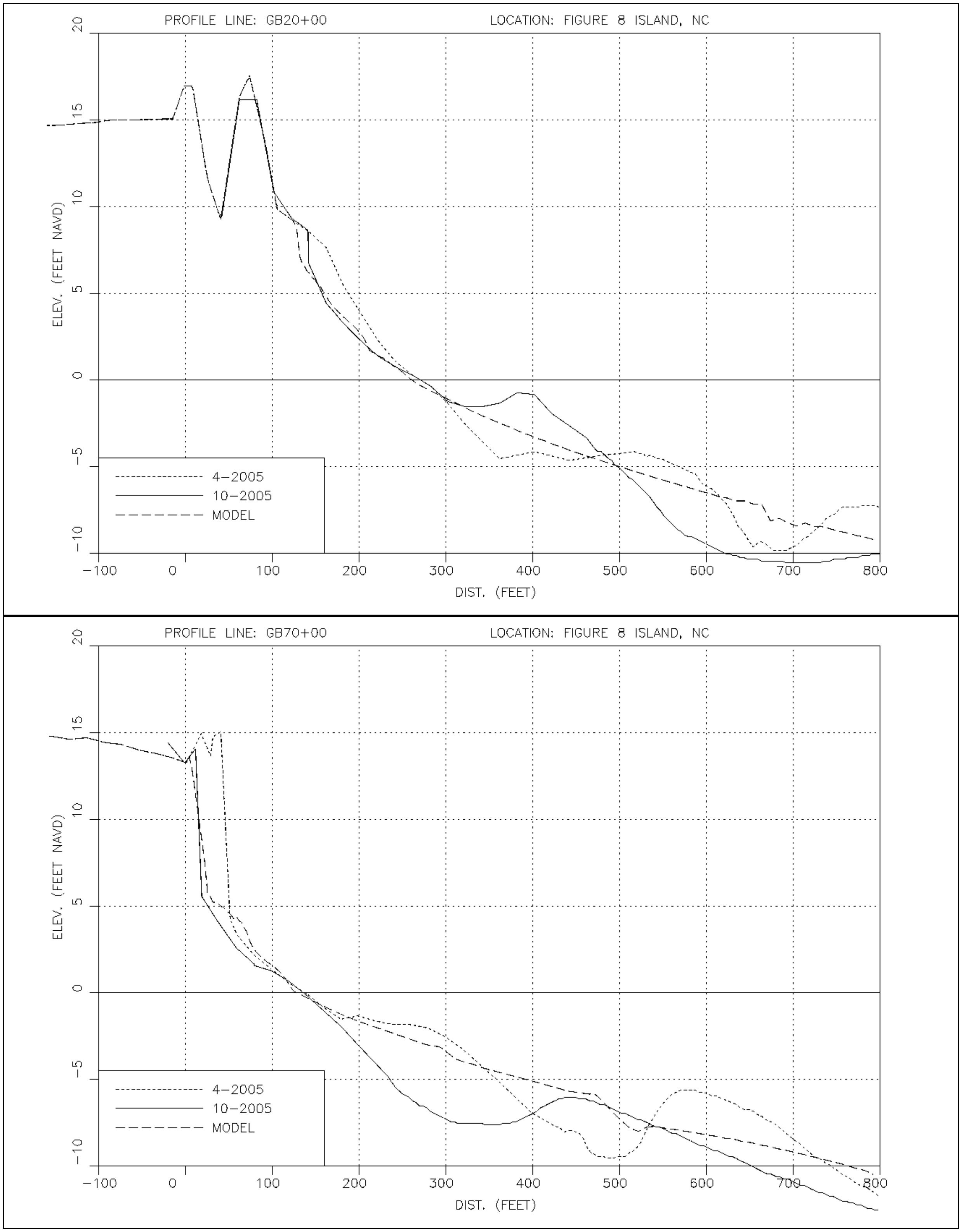



**FIGURE 10-2: SBEACH Calibration Results, Profiles 20+00 and 70+00.**

## 11.0 LONG-TERM PROJECT PERFORMANCE – DELFT3D MODEL STUDY

To evaluate the long-term performance of the various alternatives in Section 9.0, this study utilizes an advanced 2D/3D integrated modeling environment known as Delft3D (WL | Delft, 2005). Delft3D consists of two models that run together to estimate wave transformation, currents, water level changes, sediment transport, erosion, and deposition. Waves in Delft3D are simulated using SWAN (Simulating Waves Nearshore), an advanced wave transformation model that simulates breaking, shoaling, refraction, diffraction, wind stress, and bottom friction. Delft3DFLOW simulates currents, water level changes, erosion, sediment transport, erosion, and deposition based on the forcing of the tides, storm surges, waves, and winds. Delft3DFLOW and SWAN run simultaneously, exchanging wave, water level, current, and bottom depth values. Delft3D can simulate relevant coastal processes over short-term (days-storms) or long term (seasons-years) time scales.

### 11.1 Wave Model Calibration

Waves in the Delft3D modeling package were simulated using SWAN. Wave transformation estimates within the model utilized a spectral wave approach that treated each observed wave as a superposition of individual waves with varying frequencies and periods.

The primary inputs to the SWAN model were the bottom bathymetry, the time-dependent water levels, and the offshore waves. Additional inputs were the wave breaking coefficients, the bottom roughness scale, the diffraction coefficients, and the non-linear triad coefficients that governed wind effects. The parameter with the largest effect on the transformed wave field was the bottom roughness scale, which governed the bottom friction. Accordingly, calibration of the SWAN model was performed by examining the effect of bottom roughness on the nearshore wave height.

Several wave gages have been deployed in the region at various times, albeit separated by large distances (~ 20 to 50 miles) (Figure 11-1). Thus, the SWAN model was calibrated on a regional basis. Calibration runs were based on an easterly wave event at offshore wave gage LEJ3 (Figure 11-1) in July 2006. Concurrent wave measurements were taken at nearshore wave gage ILM1 (Figure 11-1), located on Johnny Mercer's Pier in Wrightsville Beach. The offshore waves, water levels, and wind velocities used in the model appear in Figures 11-2 to 11-4. Given the information that was available, wind velocities and water levels were assumed to be uniform over the model grid.

Calibration runs were conducted using bottom roughness scale from 0.00075 m to 0.05 m (0.2 inches to 13 inches). A reasonable agreement between the simulated and observed wave heights at gage ILM1 was achieved with a bottom roughness scale of 0.01 m (2.5 inches). The average difference between the observed and simulated wave height at gage ILM1 was -0.1 feet, with a root-mean-square difference of 0.4 feet. Matching the nearshore wave direction was more difficult. Simulated waves at gage ILM1 were more oblique to the shoreline than the observed waves. This occurred due to the tendency of the model to refract the waves parallel to the shoreline, as shown in Figure 11-5. The effect was more pronounced in the second half of the run, when there was a significant difference between wave periods at gages LEJ3 and ILM1. As shown in Figure 11-4, the prevailing winds at LEJ3 were from the northeast during the calibration period. Thus, the wind direction, combined with the bathymetry, had a large influence on the simulated wave direction. Based on the available information, a uniform wind velocity was assumed over the model grid. However, given the 48 mile distance between gages LEJ3 and ILM1, local variations in the wind speed and direction were likely during the calibration period. Overall, differences between the simulated and measured wave direction at gage ILM1 were probably due to the assumption of uniform winds.

Verification runs were based on a southerly wave event at offshore wave gage 41013 (Figure 11-1) in June 2004. Typical wave patterns during this even appear in Figure 11-6. Concurrent wave measurements were taken at nearshore wave gage OB3M (Figure 11-1). The offshore waves, water levels, and wind velocities used in the model appear in Figures 11-7 to 11-9. Similar to the calibration, wind velocities and water levels were assumed to be uniform over the model grid. The bottom roughness scale was set to 0.01 m (2.5 inches). Overall, agreement between the model results and the observations at OB3M was good. The average difference between the observed and simulated wave height at gage OB3M was +0.4 feet, with a root-mean-square difference of 0.6 feet. The average difference between the observed and simulated wave direction at gage OB3M was +1 degree. The verification showed that the SWAN model was able to accurately estimate nearshore wave heights, with reasonable approximations of the nearshore wave direction given a relatively uniform wind field. Based on the results in Figures 11-2, 11-3, 11-7 and 11-8, the calibrated SWAN model was judged to be suitable for estimating project performance.

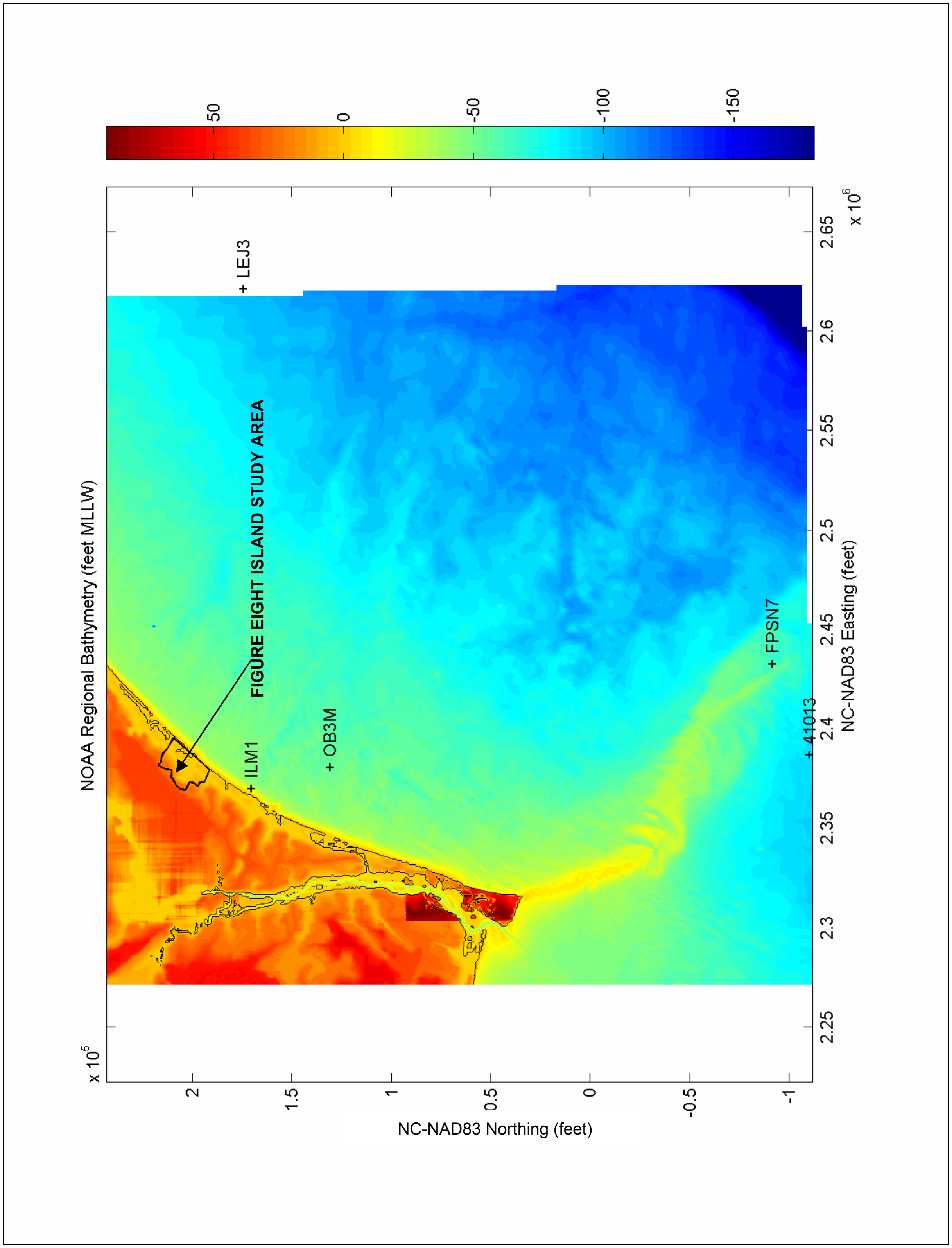



**FIGURE 11-1: Wave Calibration Bathymetry based on NOAA (2006) Regional Grid, Figure Eight Island, NC.**

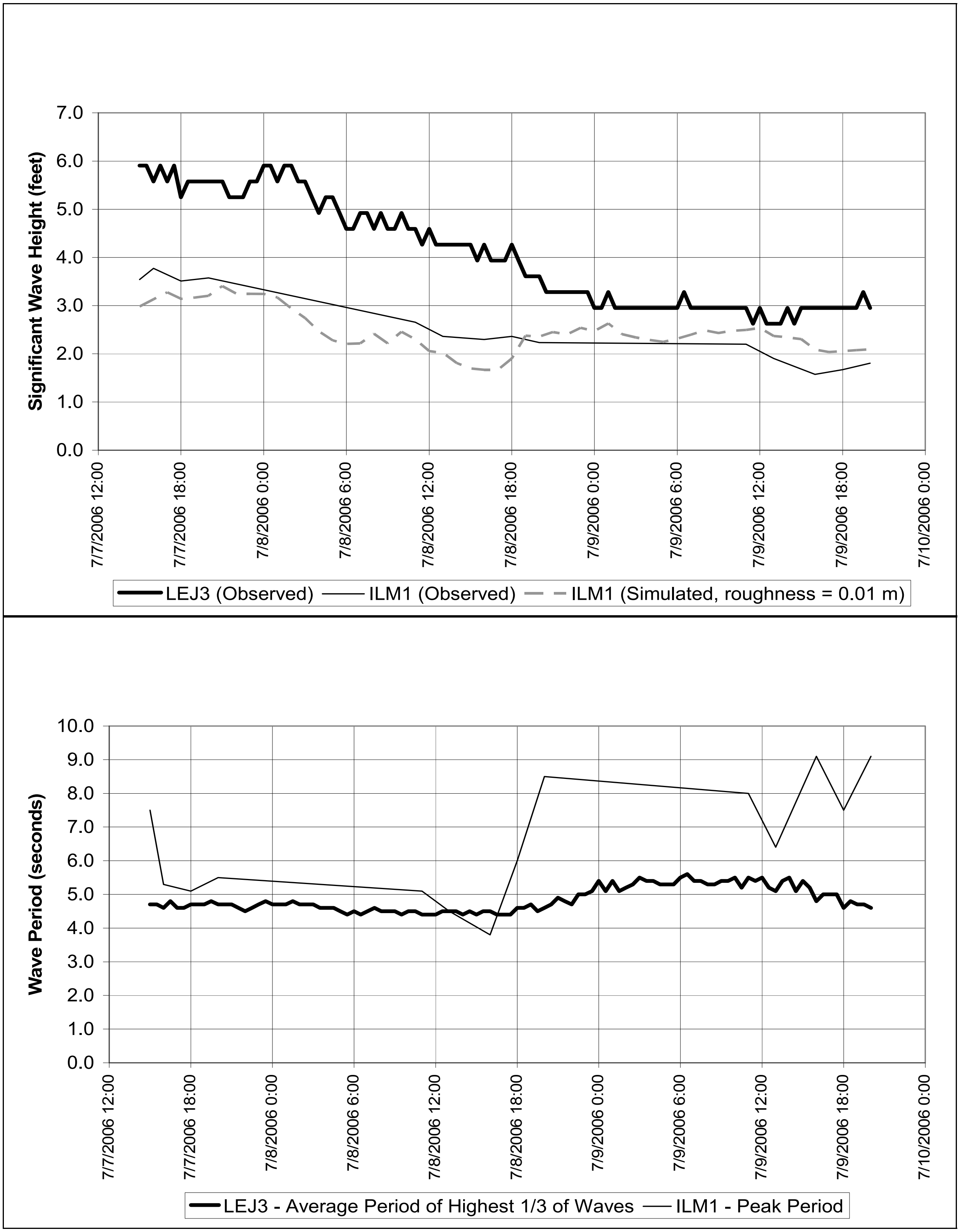



**FIGURE 11-2: Delft3D-SWAN Calibration, Wave Height and Wave Period.**

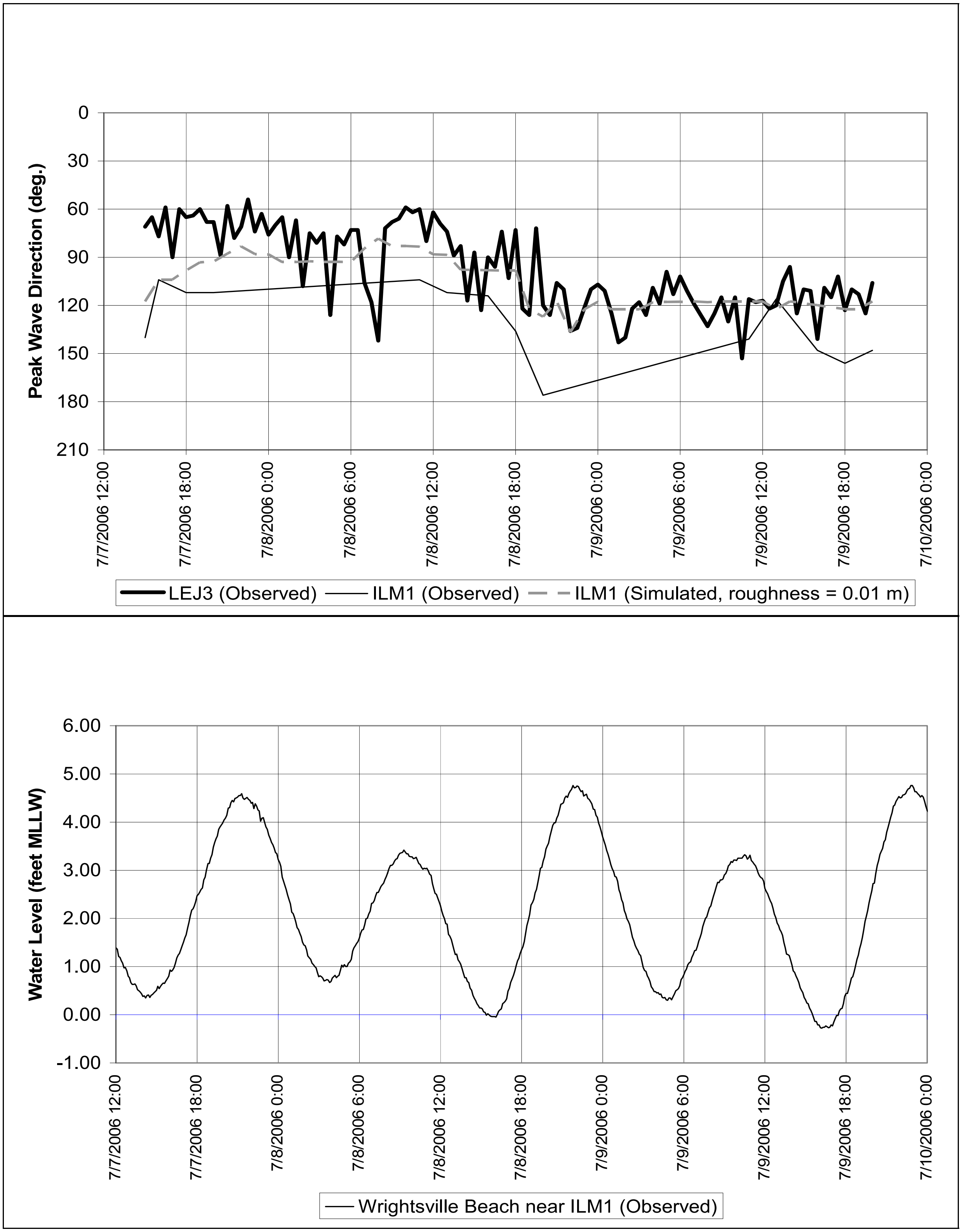



**FIGURE 11-3: Delft3D-SWAN Calibration, Wave Direction and Water Level.**

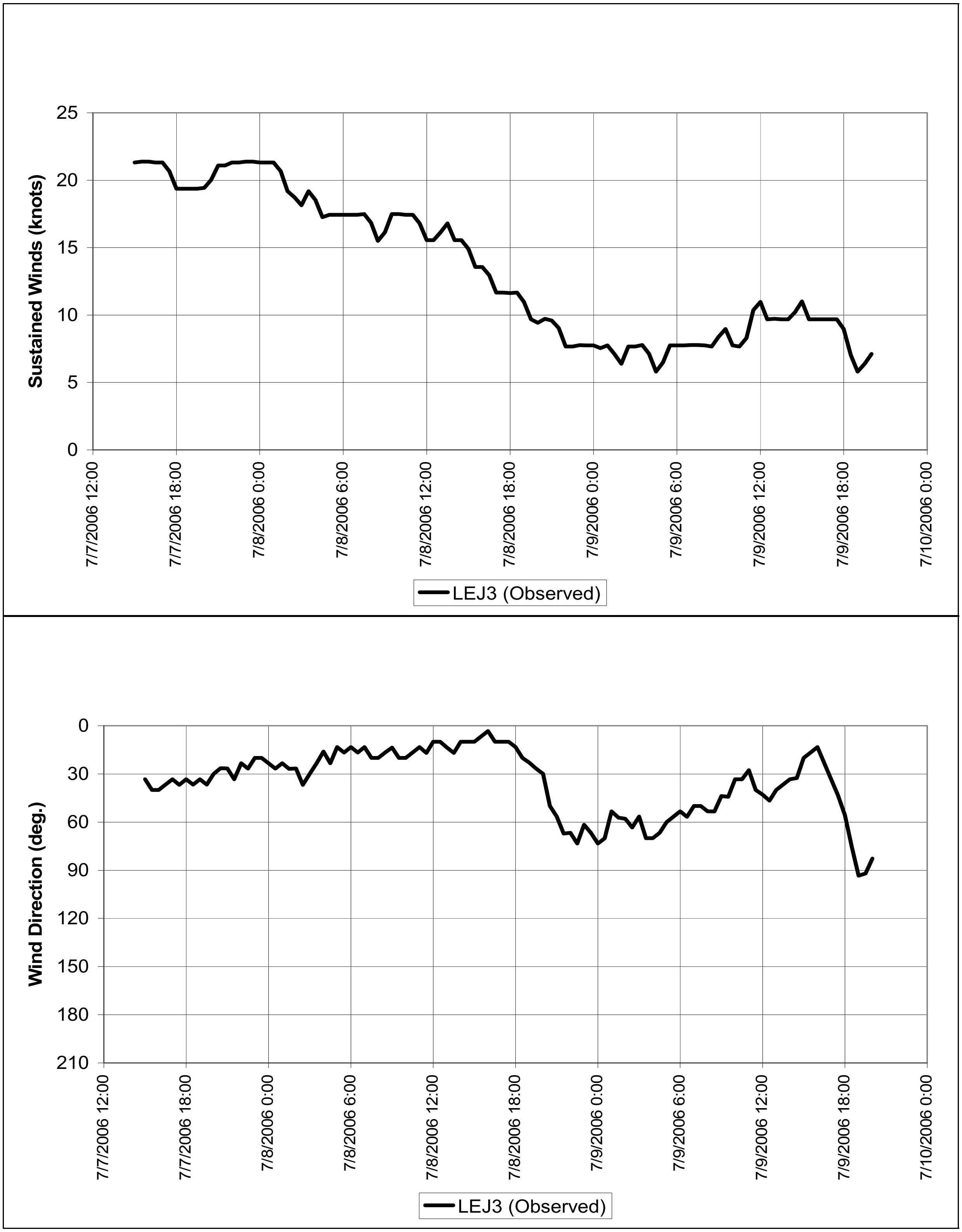



**FIGURE 11-4: Delft3D-SWAN Calibration, Wind Velocity.**

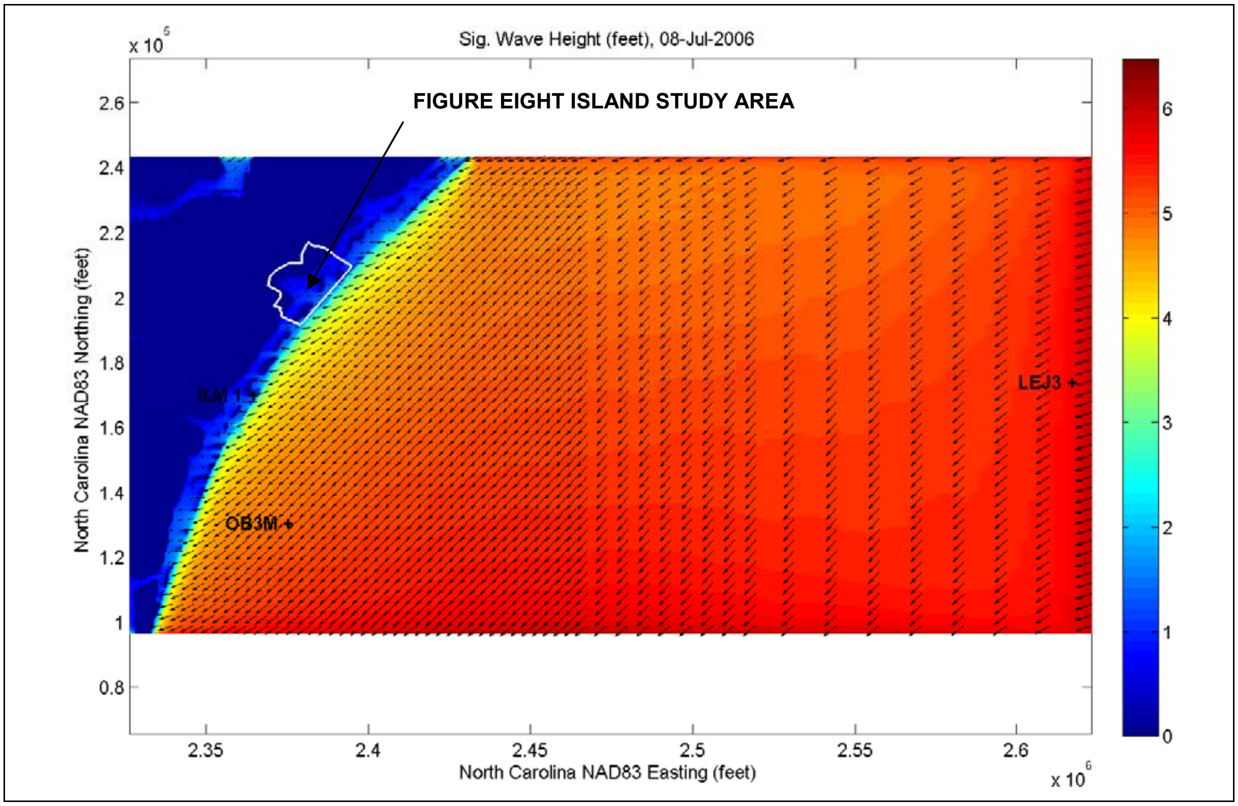



**FIGURE 11-5: Typical Wave Calibration Results, Figure Eight Island, NC.**

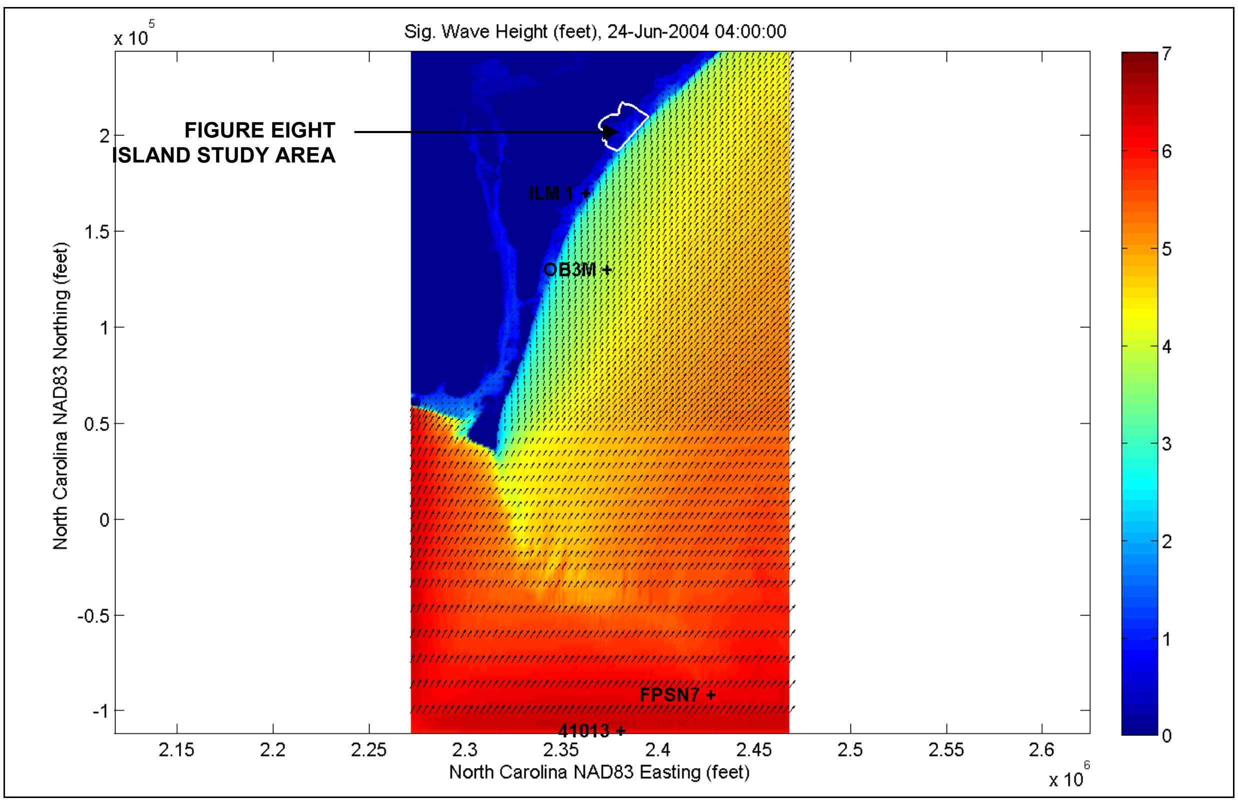



**FIGURE 11-6: Typical Wave Verification Results, Figure Eight Island, NC.**

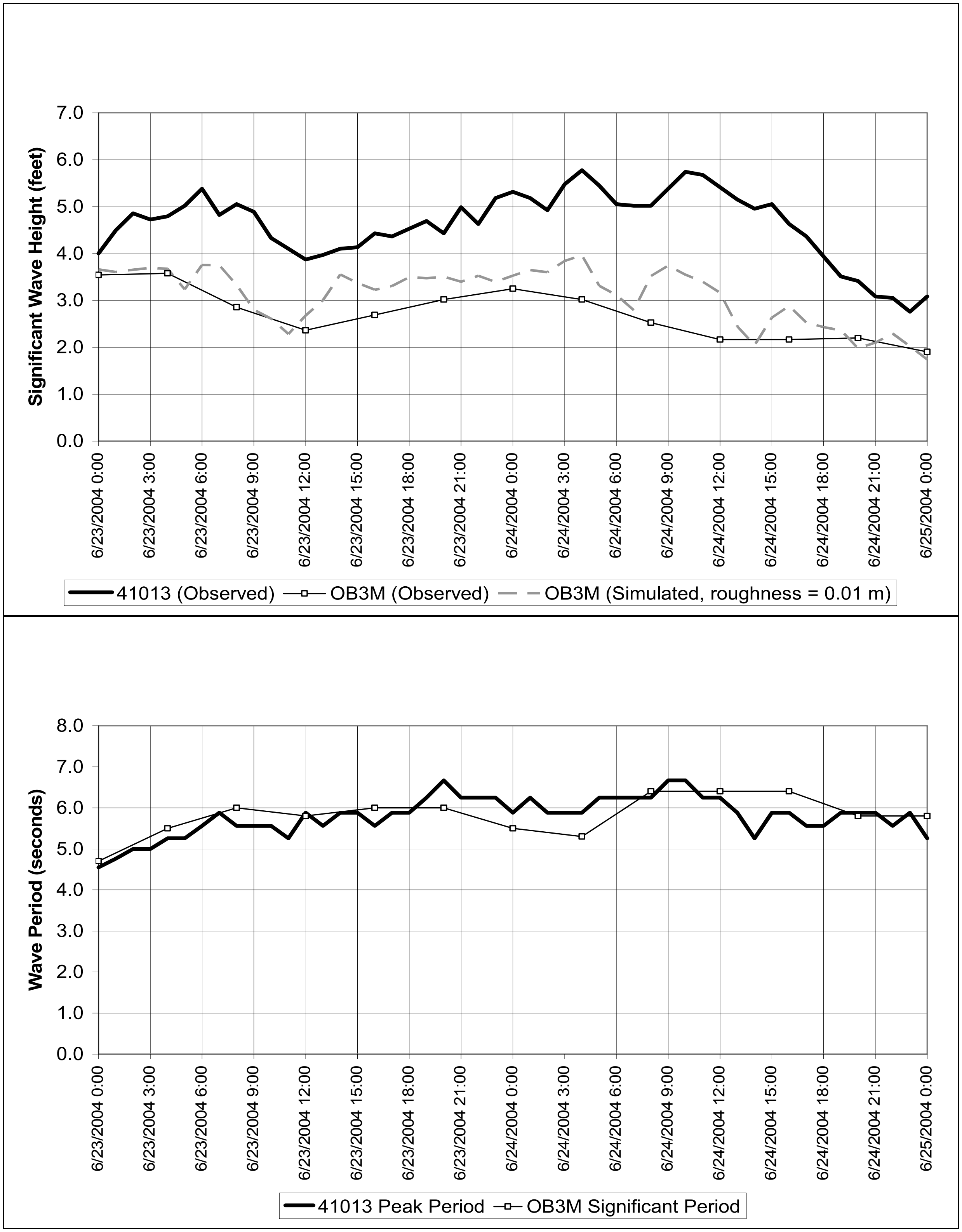



**FIGURE 11-7: Delft3D-SWAN Verification, Wave Height and Wave Period.**

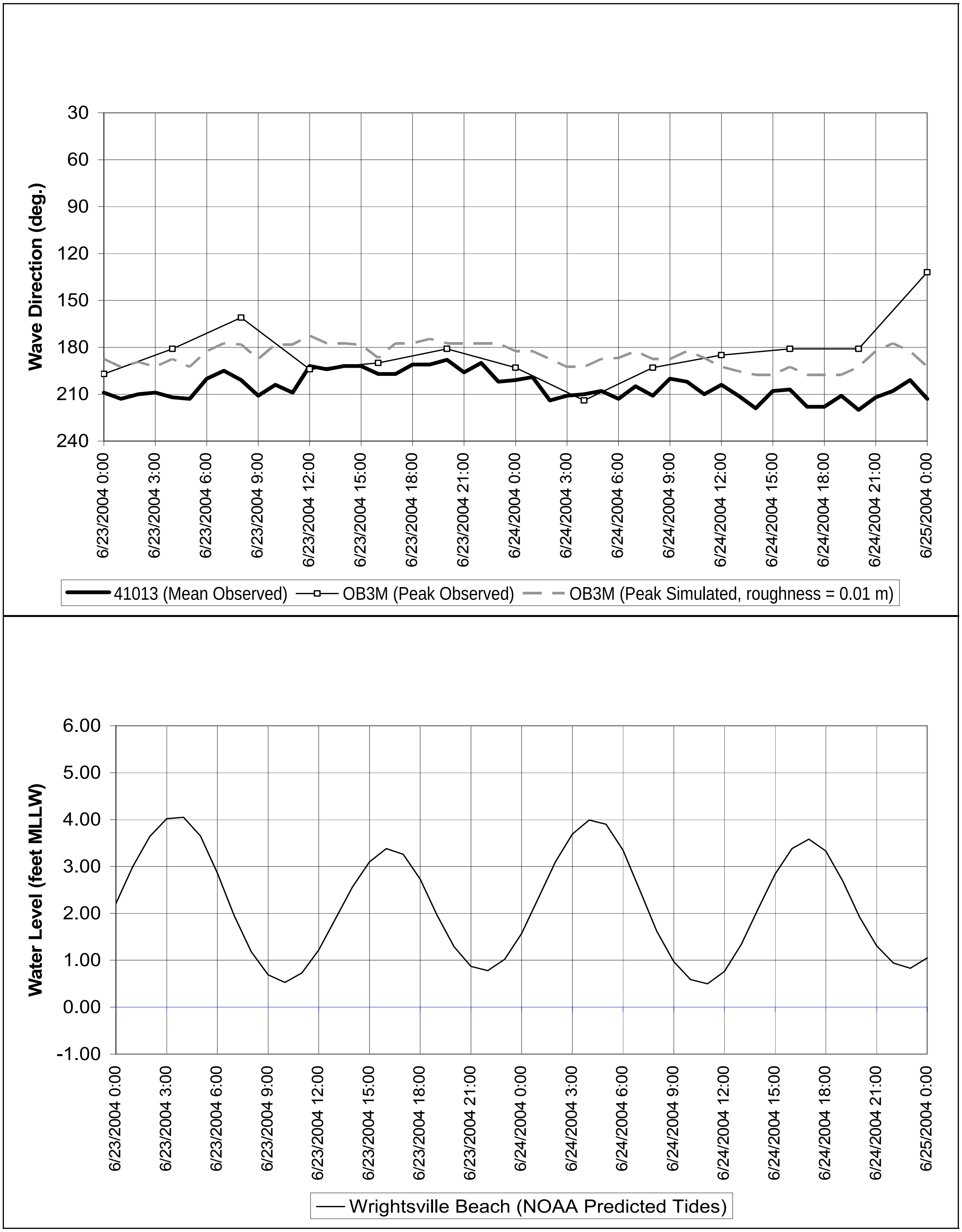



**FIGURE 11-8: Delft3D-SWAN Verification, Wave Direction and Water Level.**

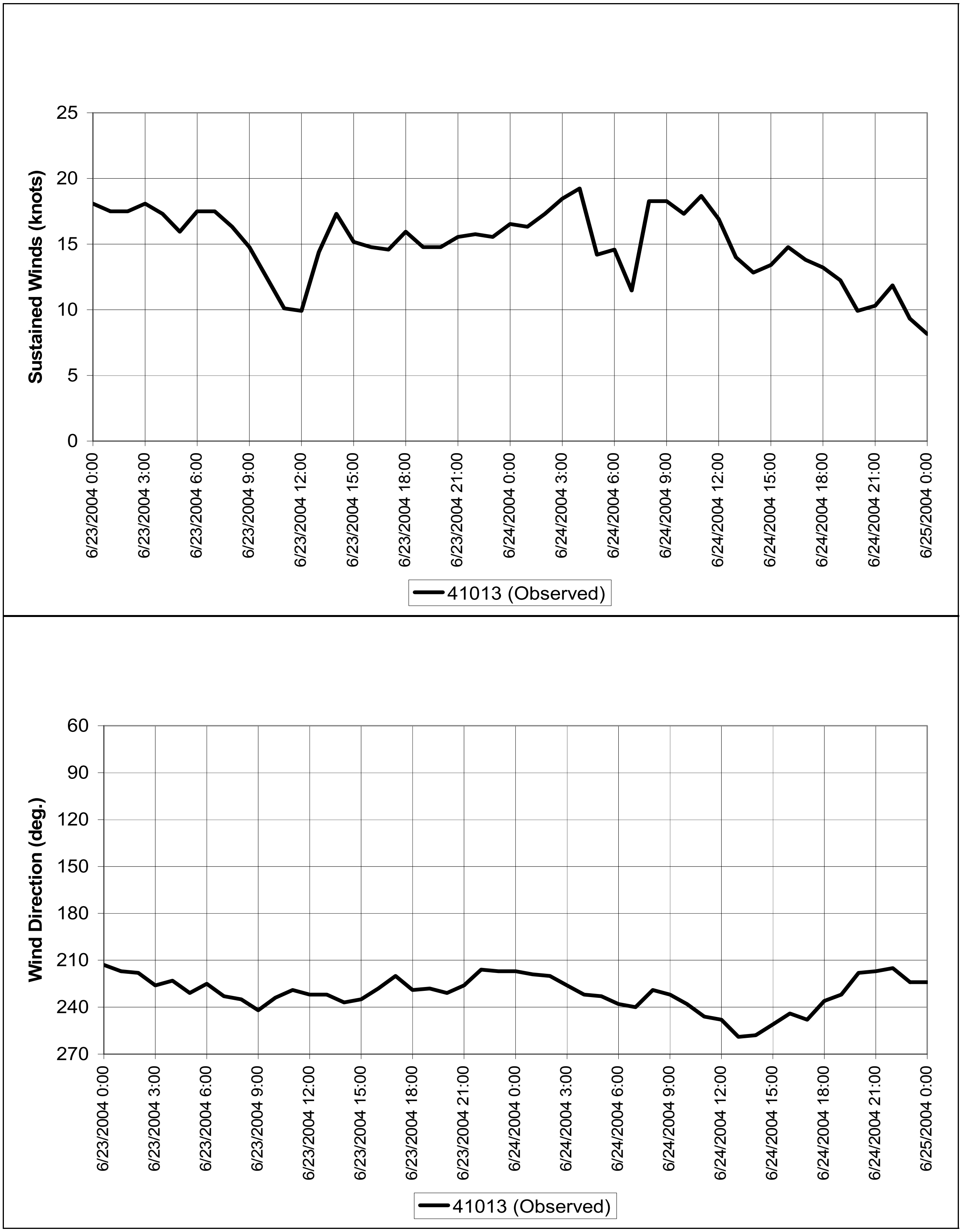



**FIGURE 11-9: Delft3D-SWAN Verification, Wind Velocity.**

## 11.2 Current and Water Level Calibration

### 11.2.1 Grids

Currents and water levels in the Delft3D modeling package were simulated using Delft3DFLOW. The model's currents and water levels were calibrated friction using a set of water level and current measurements provided by Gahagan & Bryant (2006) (see Section 4.3). Water levels were measured at seven (7) tide gages deployed May 25 - July 7, 2005, as shown in Figure 4-1. In addition, velocities were measured at three (3) locations on June 21, 2005 using boat-mounted Acoustic Doppler Current Profilers (ADCPs). Observed currents were reported by Gahagan & Bryant on a depth-averaged basis. The calibration run was performed using Delft3DFLOW in conjunction with SWAN, to account for the influence of both waves and tides.

Four grids were used in the flow calibration and subsequent model runs (Table 11-1 and Figures 11-10 to 11-16):

- Regional Wave Grid. The purpose of this grid was to simulate wave transformation over the region extending from Ocracoke, NC to Pawleys Island, SC. The offshore grid boundary generally followed the -500 foot NAVD depth contour. By simulating wave transformation over this area, it was possible to account for the influence of Cape Lookout and Cape Fear on the local wave patterns (Figures 11-10 through 11-12).

- Intermediate Wave Grid. The purpose of this grid (Figures 11-10, 11-11, and 11-13) was to provide more detailed wave information along the boundaries of the Local Wave Grid. This Intermediate Wave Grid extended from Surf City to Masonboro Island.

- Local Wave Grid. The purpose of this grid was to provide detailed wave information along the project area in shallow water. This grid extended from the midpoint of Hutaff Island to Mason Inlet. Wave transformation estimates along this grid were fed into the Delft3DFLOW model to estimate the wave-driven currents. Currents and water levels estimated by the Delft3DFLOW model were fed into the SWAN model to account for the influence of tidal currents and water level changes over this grid. Over the other two wave grids, tidal currents and water level changes were neglected by the SWAN model (Figures 11-10, 11-11, and 11-14).

- Flow Grid. This grid was utilized to estimate tidal currents and water level changes. Like the Local Wave Grid, this grid extended from Hutaff Island to Mason Inlet. However, to include all of the area drained by Rich Inlet, the grid was extended towards the west (Figures 11-15 and 11-16).

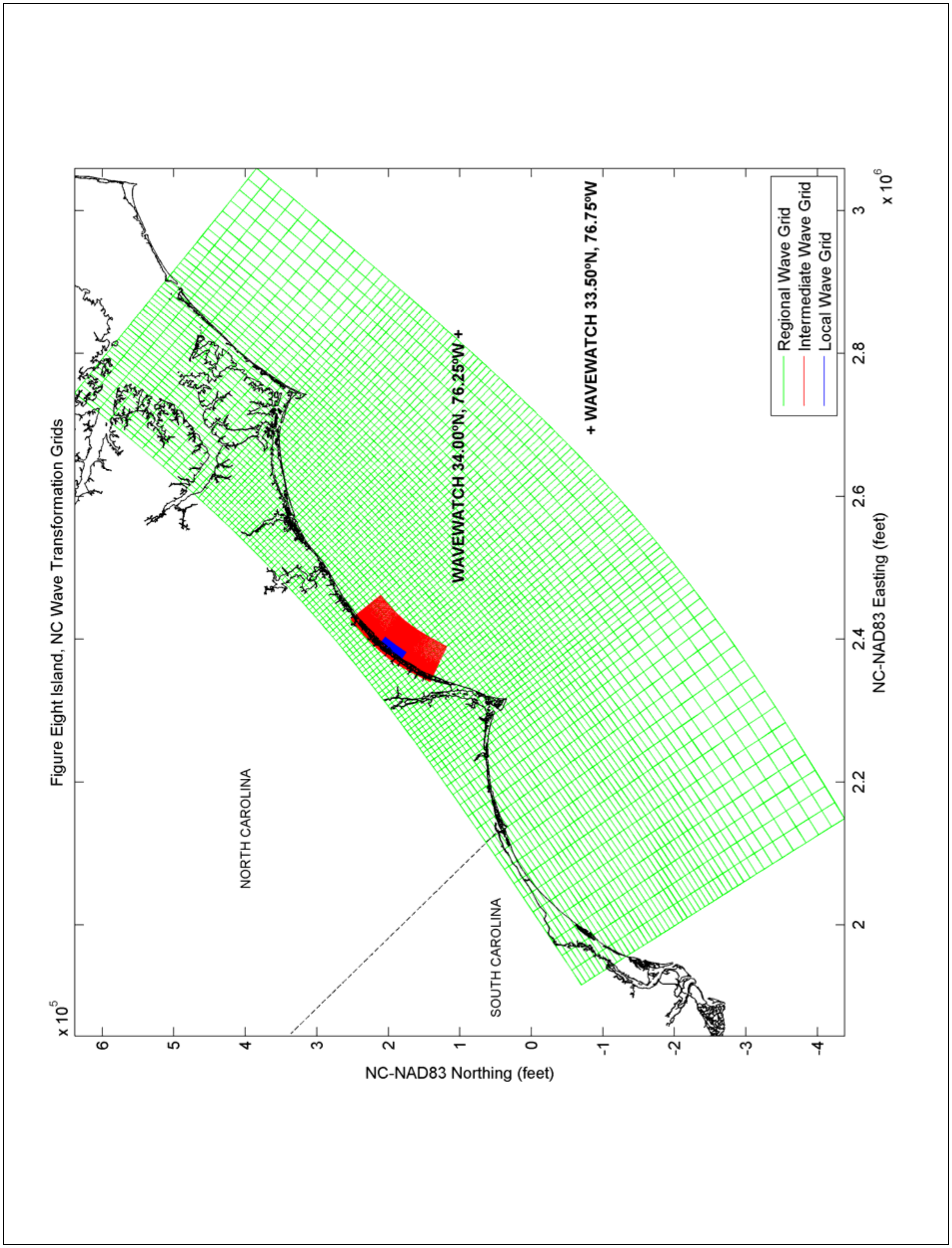



**FIGURE 11-10: Wave Transformation Grids used in Delft3DFLOW Calibration and Subsequent Model Runs.**

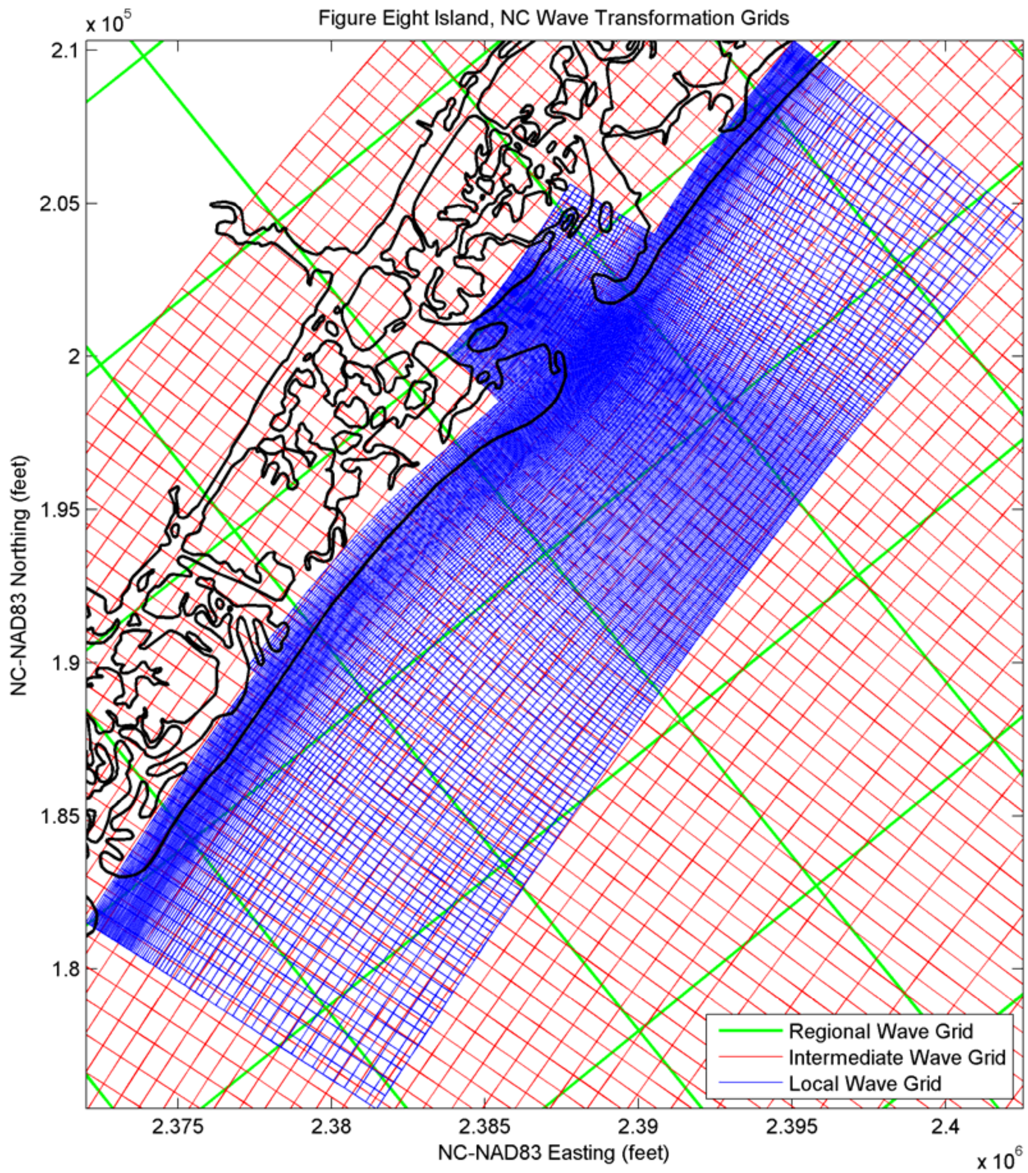



**FIGURE 11-11: Wave Transformation Grids used in Delft3DFLOW Calibration and Subsequent Model Runs (closeup).**

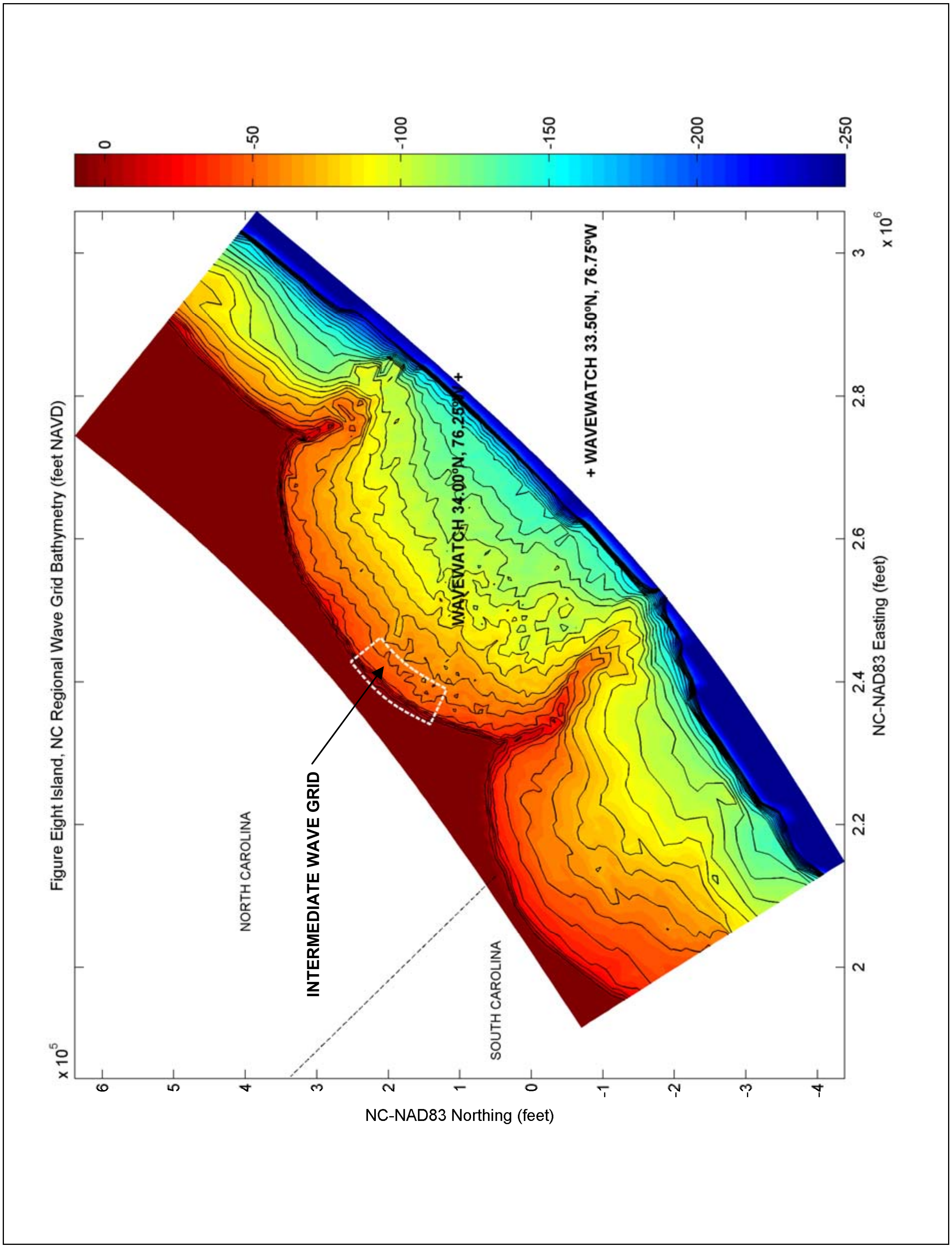



**FIGURE 11-12: Bathymetry over the Regional Wave Grid.**

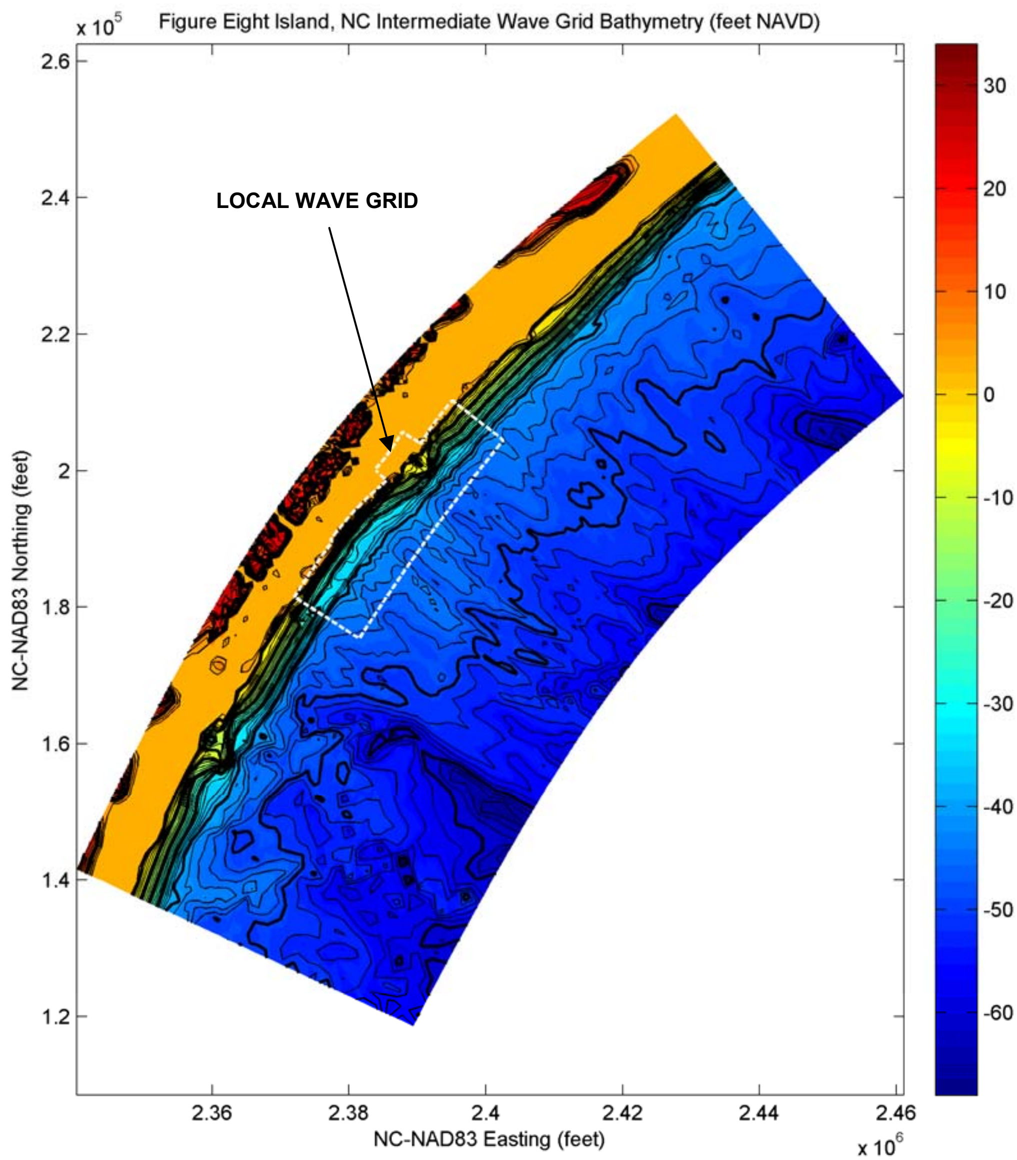



**FIGURE 11-13: Bathymetry over the Intermediate Wave Grid.**

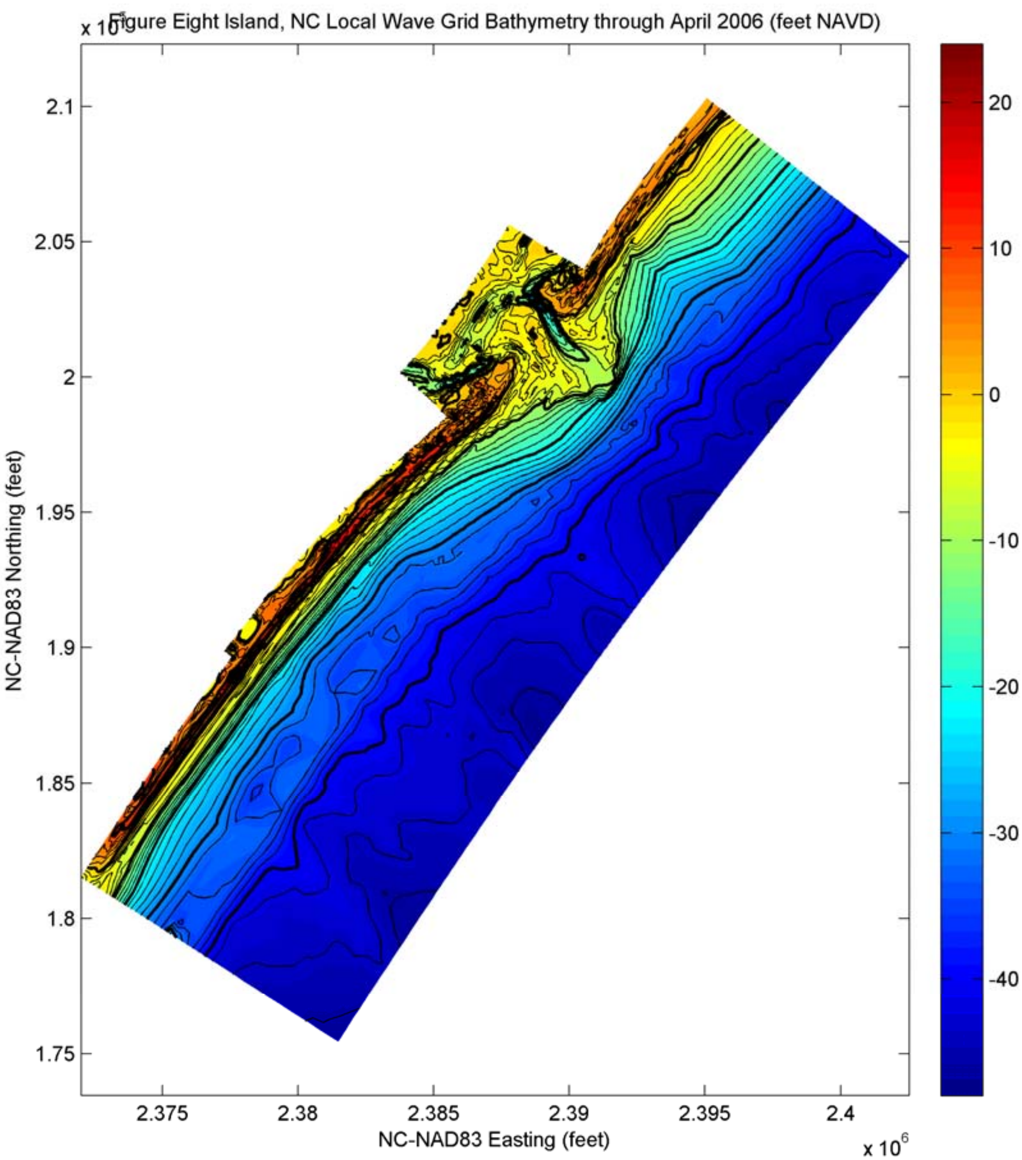



**FIGURE 11-14: Bathymetry over the Local Wave Grid.**

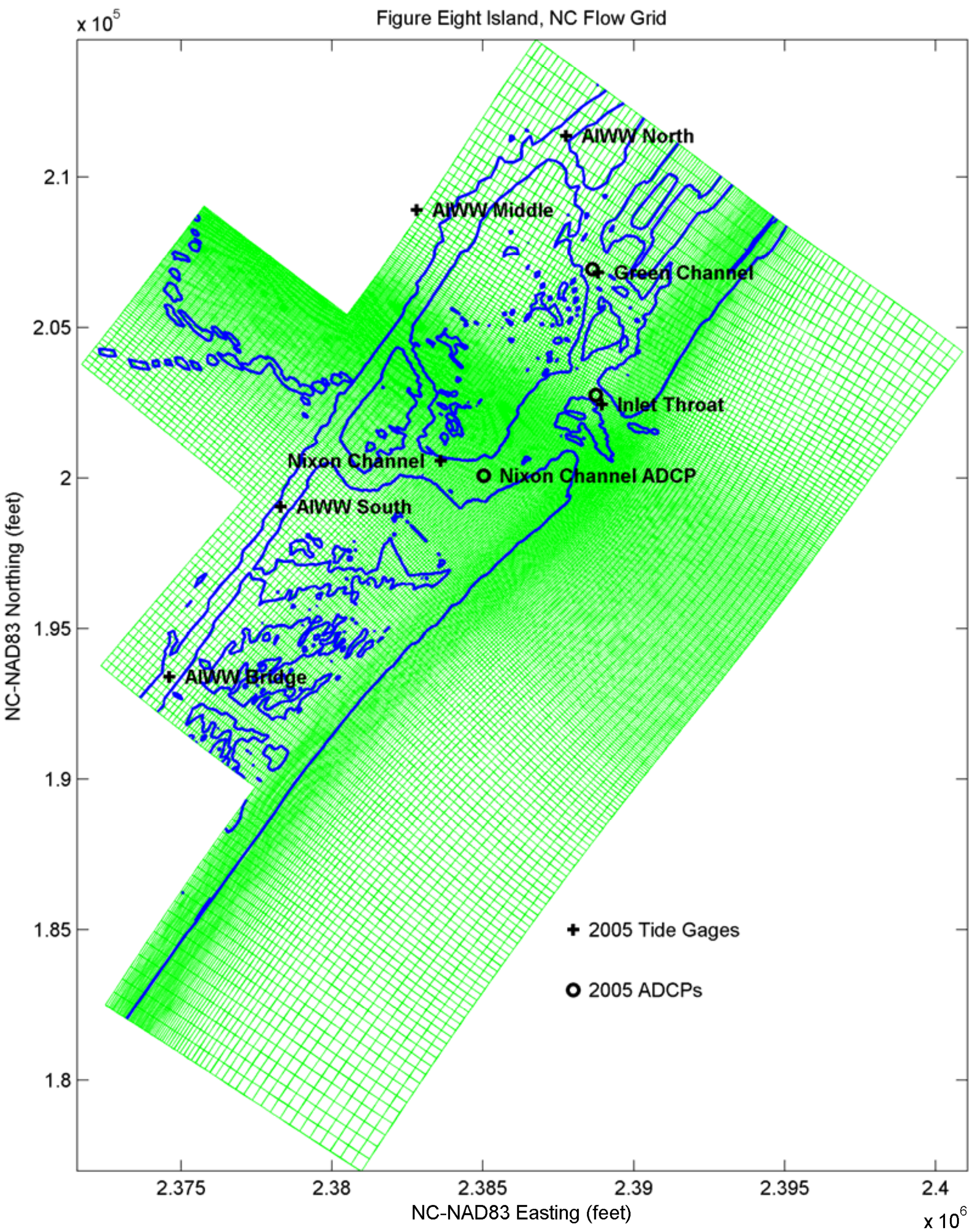



**FIGURE 11-15: Flow Grid.**

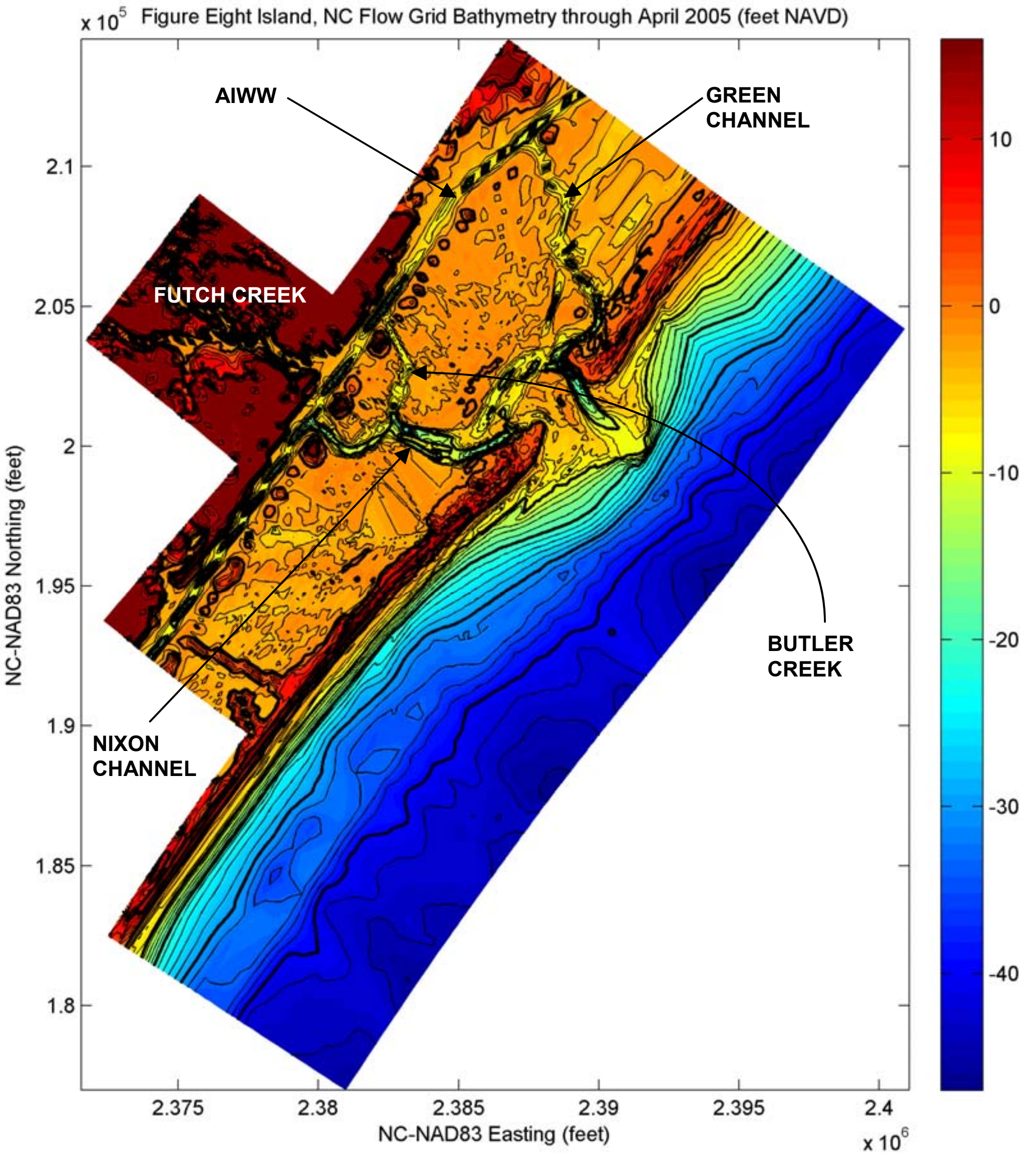



**FIGURE 11-16: Bathymetry over the Flow Grid.**

**TABLE 11-1**

**GRIDS USED IN DELFT3D MODEL**
**FIGURE EIGHT ISLAND, NC**

| Grid | Longshore Grid Cells | Cross-Shore Grid Cells | Longshore Grid Spacing (feet) | Cross-Shore Grid Spacing (feet) |
|---|---|---|---|---|
| Regional Wave Grid | 101 | 47 | 6,977 - 23,366 | 6,575 - 23,375 |
| Intermediate Wave Grid | 113 | 54 | 582 - 2,194 | 629 - 2,144 |
| Local Wave Grid | 248 | 93 | 38 - 542 | 40- 420 |
| Flow Grid | 248 | 153 | 33 - 575 | 41 - 415 |

Bathymetry over the Regional and Intermediate wave grids was based on the NOAA (2006) Regional Grid (Figure 11-1). Within the Flow Grid and Local Wave Grid, the bathymetry during the calibration runs was updated to depict the conditions during calibration period (May-July 2005). Accordingly, the primary data source used to fill these grids was the April 2005 survey by Gahagan & Bryant (2006). Elevations outside April 2005 survey area were estimated from:

- The October 2005 Light Detection and Ranging (LIDAR) survey of Pender County by NOAA.
- The June 2006 survey of the Mason Inlet area by Gahagan & Bryant.
- The August 2004 LIDAR survey of Pender County by NOAA.
- The March 2002 digital elevation model produced by the North Carolina Floodplain Mapping Program.
- The NOAA (2006) Regional Grid (Figure 11-1).

The 2005 bathymetry appears in Figure 11-16. The primary bathymetric features are the inlet throat, Green Channel, Nixon Channel, the AIWW, and Futch Creek. The main channel through the inlet throat and the ebb shoal ranges from -20 to -35 feet NAVD and runs from southeast to northwest. At the landward end, it splits into Green Channel, which runs from south to north, and Nixon Channel, which runs from east to west. Both channels, which end at the AIWW, are approximately 2 miles long with a typical depth of -15 feet NAVD. In Green Channel, the channel splits in two between the Inlet Throat and Green Channel tide gages. At the landward end of Nixon Channel, Butler Creek provides a secondary connection to the AIWW. Typical depths in Butler Creek are -14 feet NAVD. Futch Creek flows into the AIWW midway between Nixon Channel and Butler Creek. The marsh between Figure Eight Island and the AIWW ranges from 1 to 1.5 miles wide. Typical elevations in the marsh are on the order of 0 feet NAVD.

During the current and water level calibration, the Delft3DFLOW model was run in three-dimensional model. Five vertical layers were assumed at each grid point, with each layer equal to 20 percent of the water depth.

### 11.2.2 Model Forcing

To calibrate the currents and water levels in Delft3DFLOW, flow patterns were simulated between May 19, 2005, 8:00 PM EDT and June 30, 2005, 8:00 PM EDT. Sediment transport, erosion, and deposition were assumed to be negligible during this period. Water levels on the offshore boundary of the Flow Grid were assumed to be equal to the measured water levels by NOAA at Wrightsville Beach (see Figures 4-3 and 11-17). Waves on the offshore boundary of the Regional Wave Grid were taken from the NOAA Wavewatch forecast for the Western North Atlantic at 33.50°N, 76.75°W, -488' NAVD (see Figures 11-12, 11-17, and 11-18). Uniform wind velocities were assumed, based on measurements by NOAA at the Wrightsville Beach tide gages (see Figures 4-3 and 11-18).

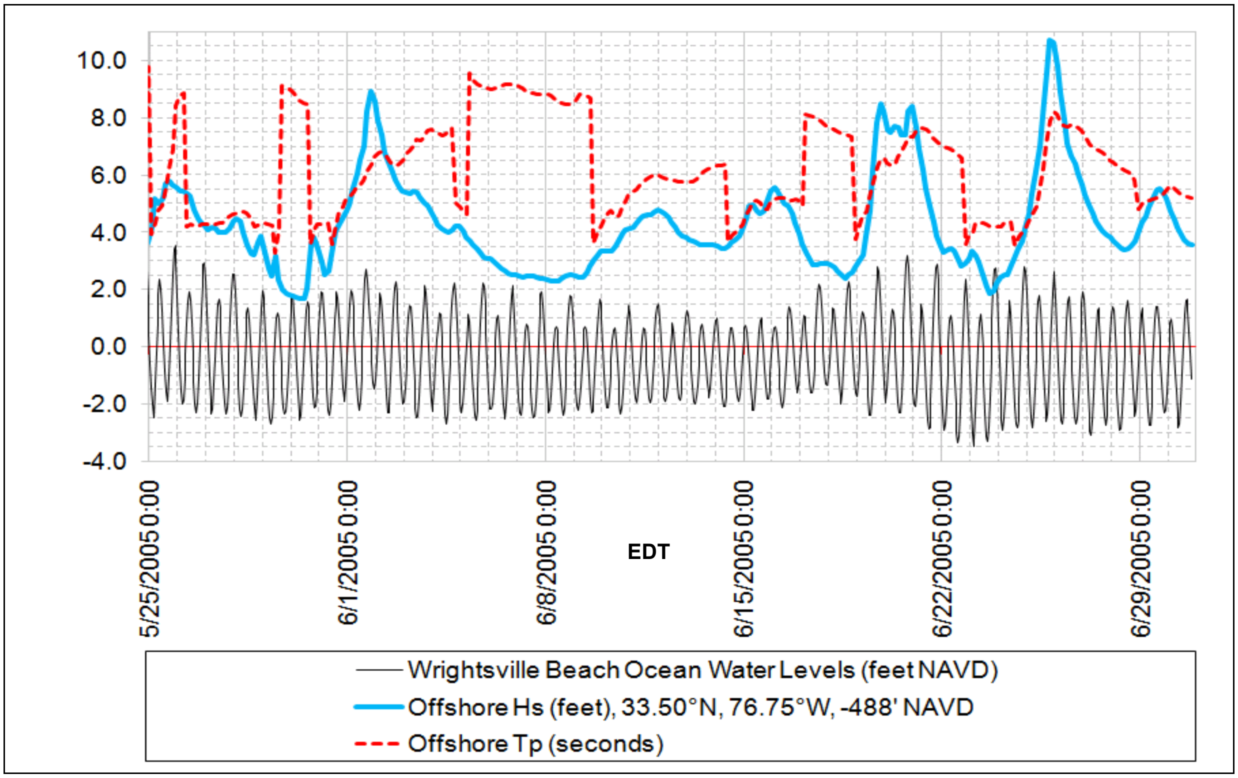



**FIGURE 11-17: Offshore Waves and Water Levels during the Delft3DFLOW Calibration.**

In both the SWAN and Delft3DFLOW models, the assignment of the upcoast and downcoast boundary conditions followed the standard modeling practices. On the northern and southern boundaries of the flow grid, zero gradient boundary conditions were assumed. Currents and water levels just outside the northern and southern boundaries were assumed to be equal to the corresponding values immediately inside. On the northeastern and southwestern boundaries of the Regional Wave Grid, the wave heights and directions outside the surf zone were assumed to be equal to their corresponding values on the offshore boundaries.

### 11.2.3 Calibration and Verification Results

To calibrate and verify the water levels and currents, Chezy's bottom friction coefficient was varied (see Figure 11-19). All other model parameters were set to their default values. Chezy's bottom friction coefficient was related to Manning's n based on the following:

Chezy's bottom friction = (Depth in meters$^{1/6}$) / (Manning's n)

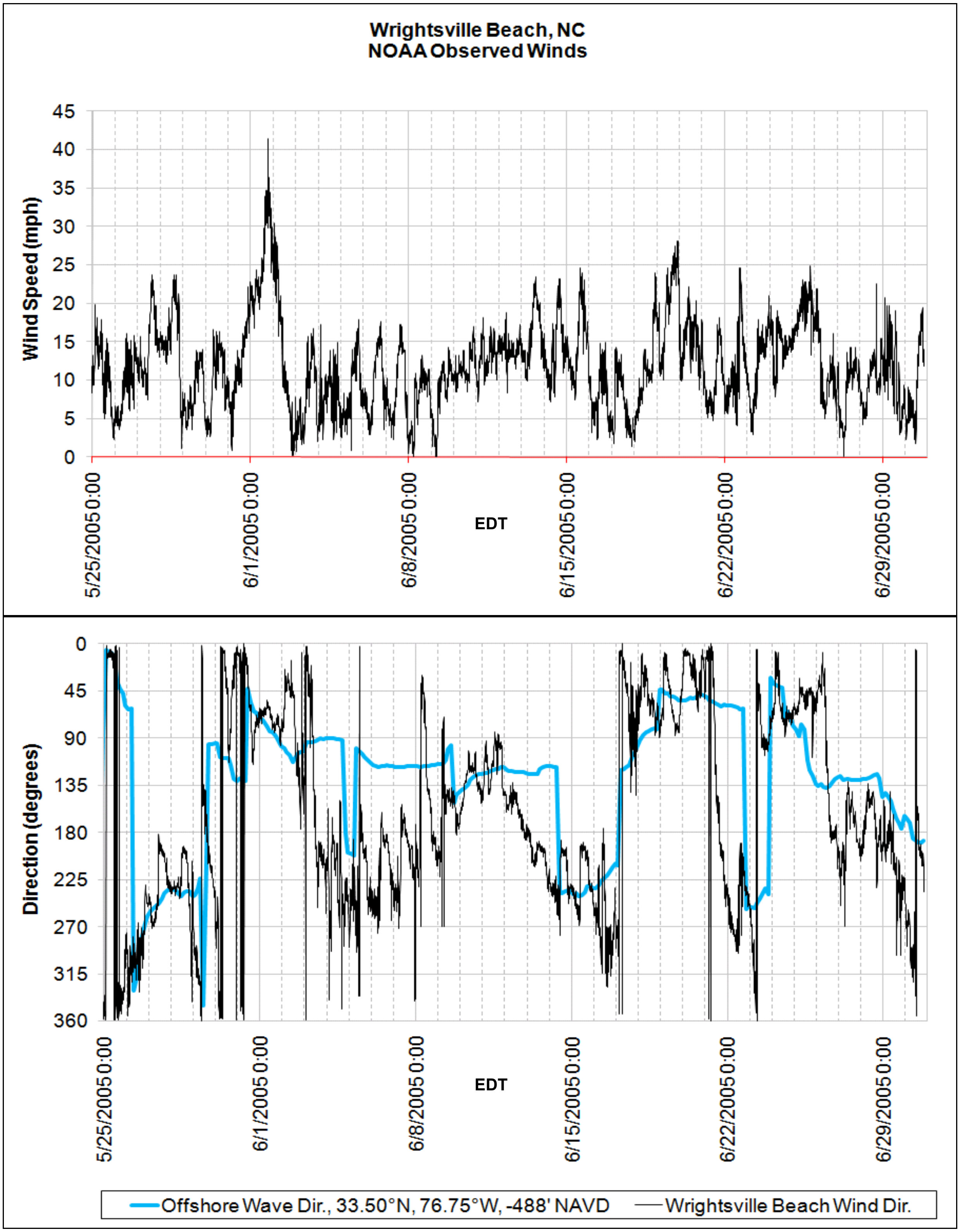



**FIGURE 11-18: Wind Velocities and Offshore Waves Directions during the Delft3DFLOW Calibration.**

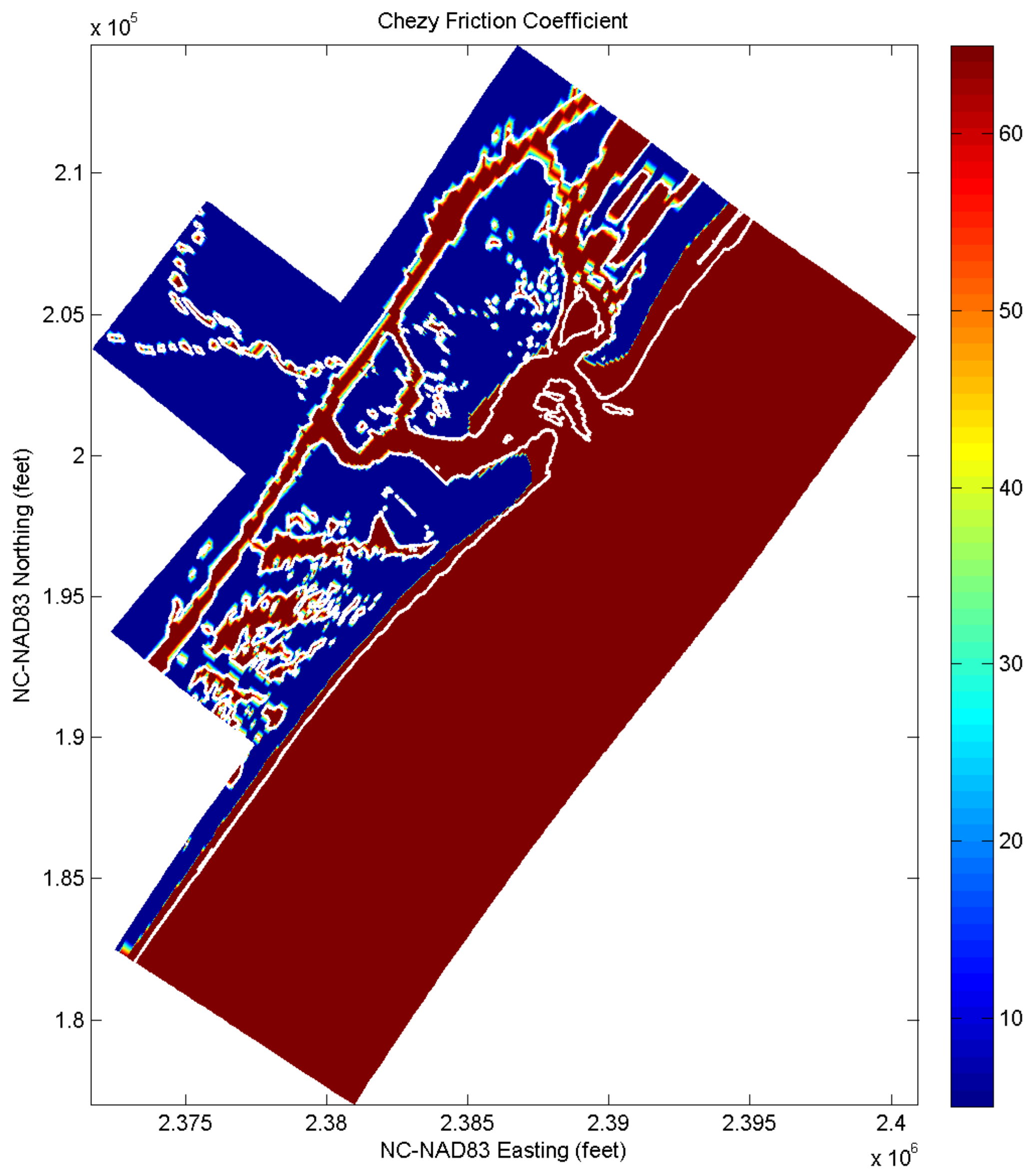



**FIGURE 11-19: Final Bottom Friction Mapping for Delft3DFLOW Model.**

Within the salt marsh and upland areas, the bottom friction coefficient was equal to 5. The equivalent value of Manning's n given a mean high water elevation of 1.7 feet NAVD and a bottom grade elevation of 0' NAVD would be 0.179. Elsewhere, the bottom friction coefficient was equal to 65, which was the model's default value. The equivalent value of Manning's n given a mean high water elevation of 1.7 feet NAVD and a bottom grade elevation of -15' NAVD would be 0.020.

Model results during spring tides on June 21, 2005 were used to calibrate the model. Agreement between the observed currents and the simulated currents was in the Inlet Throat and Nixon Channel was good (see Figures 11-20 to 11-21). Within Green Channel, differences between the simulated and observed currents occurred due to the location of the Green Channel ADCP (see Figures 11-15 and 11-22). This ADCP was deployed near the junction of the two forks within Green Channel and a side channel into the salt marsh. This location was characterized by complex currents in the model (see Figure 11-23). If the Green Channel ADCP had been deployed further inland, the model results would have been closer to the observations. Overall, the velocities predicted the by the model were reasonable within the areas being considered for dredging.

Simulated and observed water levels appear in Figures 11-24 to 11-26. Agreement between the measured and observed water levels was very good at all tide gages deployed by Gahagan & Bryant.

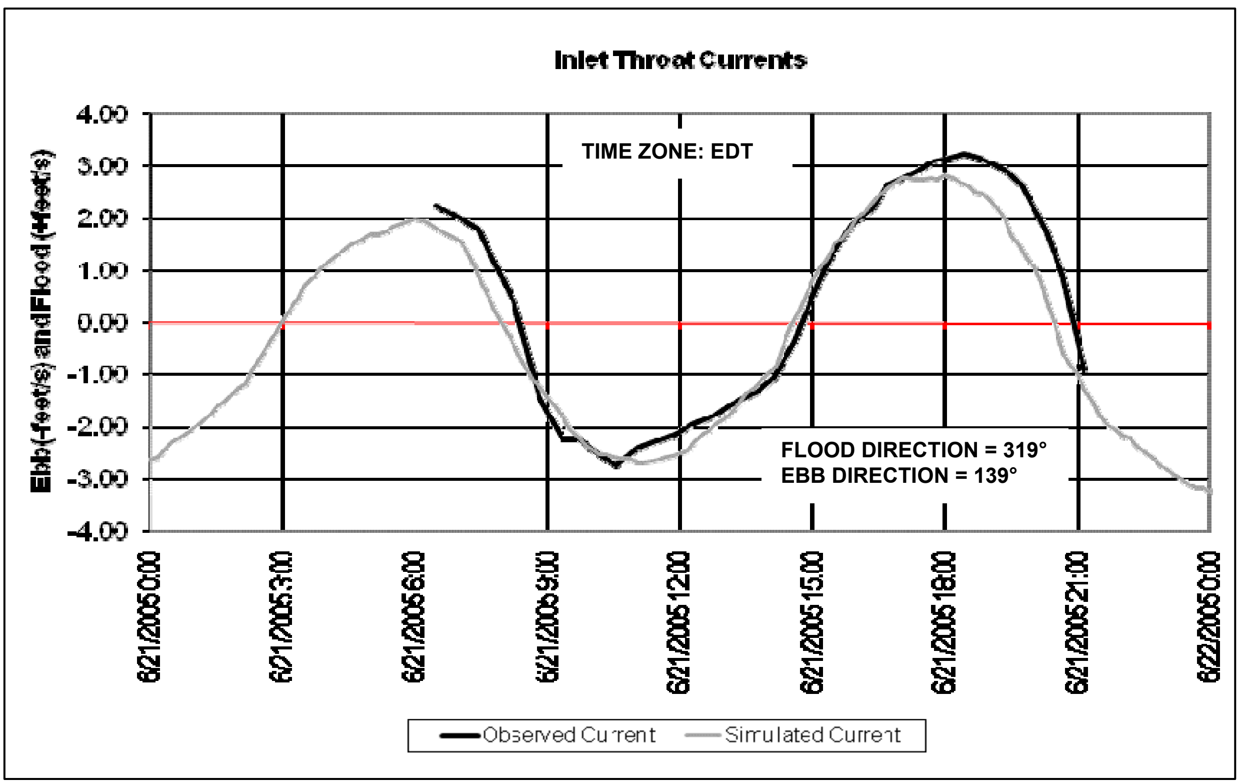



**FIGURE 11-20: Simulated and Observed Currents at the Inlet Throat ADCP.**

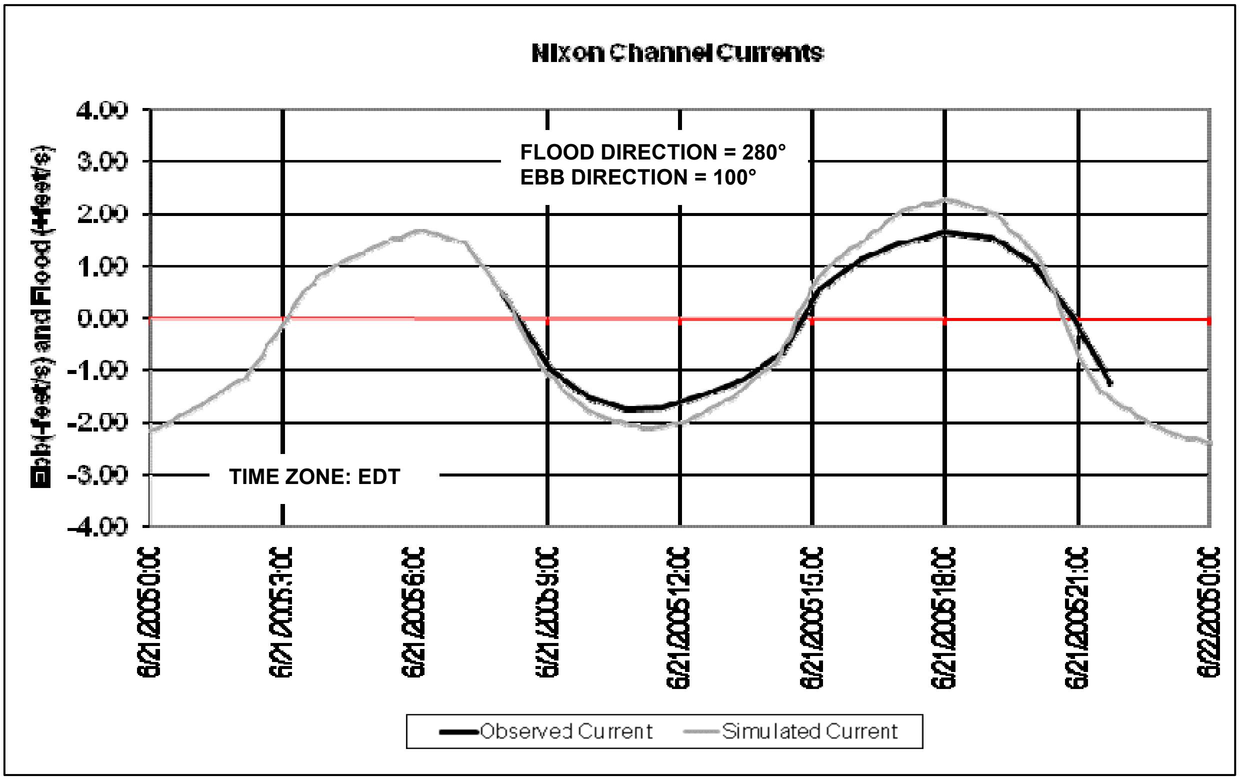



**FIGURE 11-21: Simulated and Observed Currents at the Nixon Channel ADCP.**

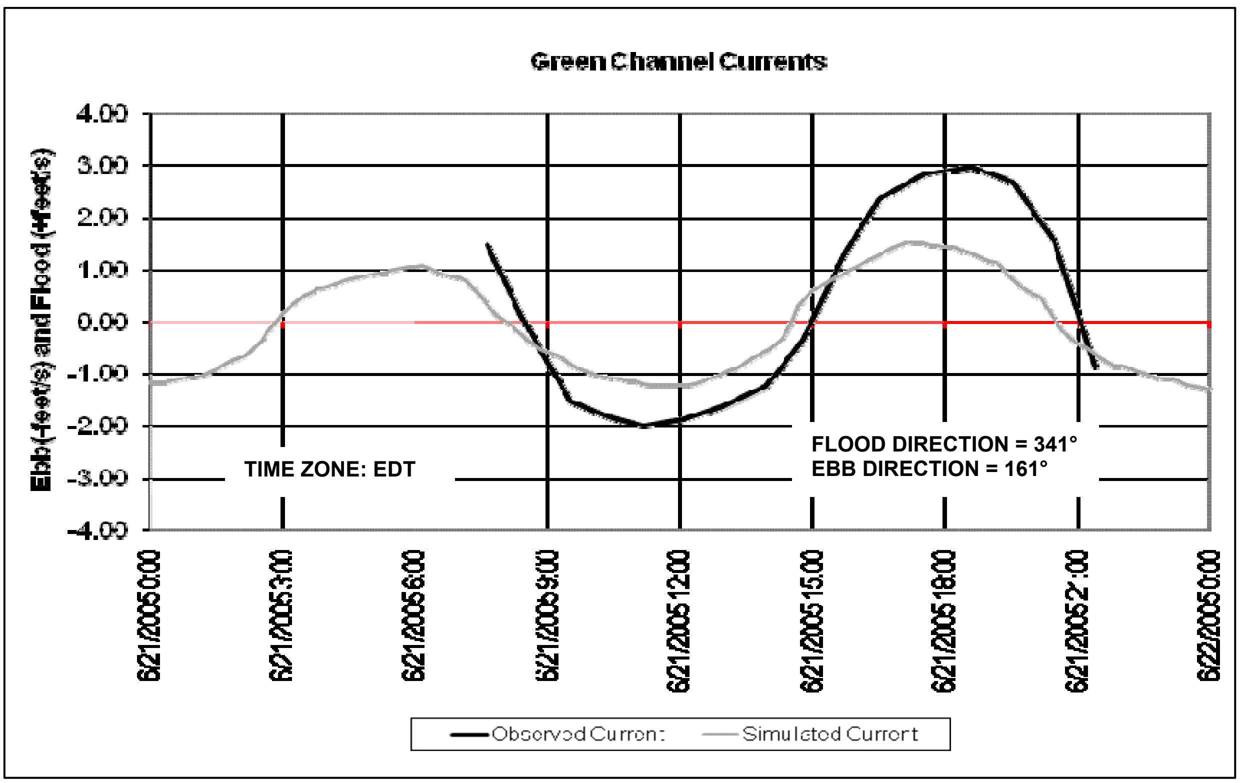



**FIGURE 11-22: Simulated and Observed Currents at the Green Channel ADCP.**

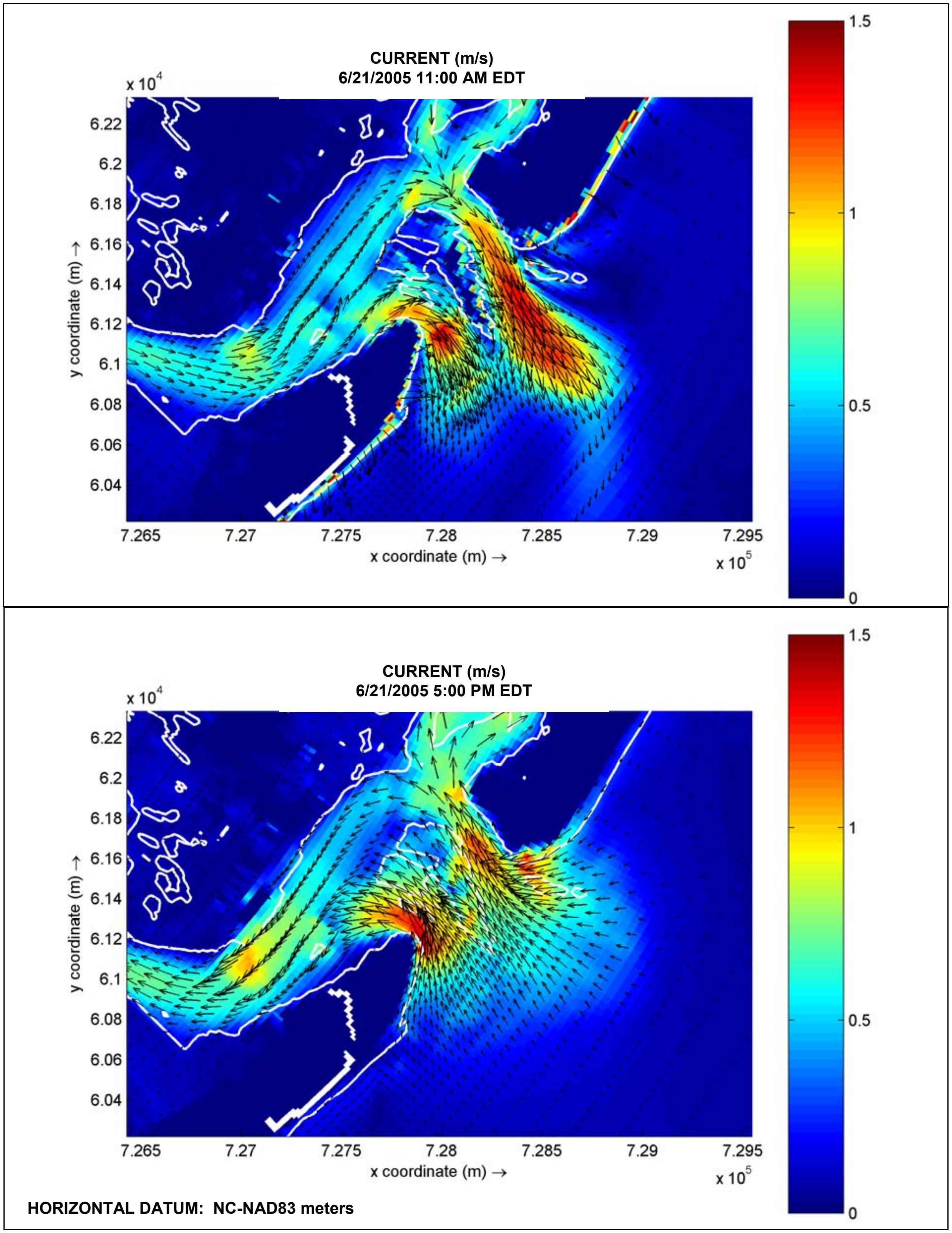
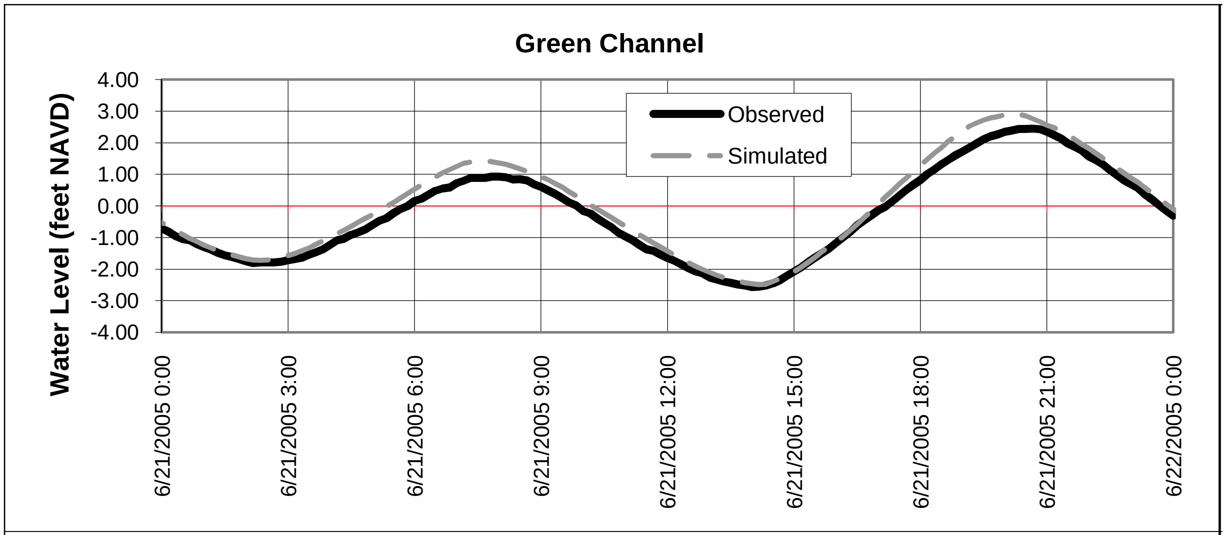
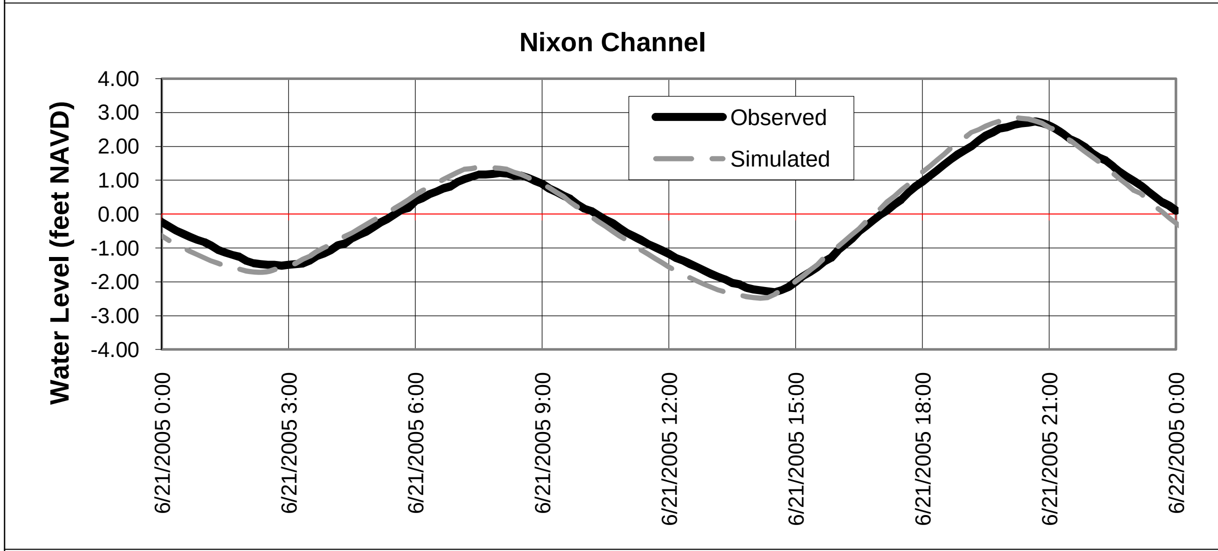



**FIGURE 11-23: Typical Simulated Currents during Spring Tides.**



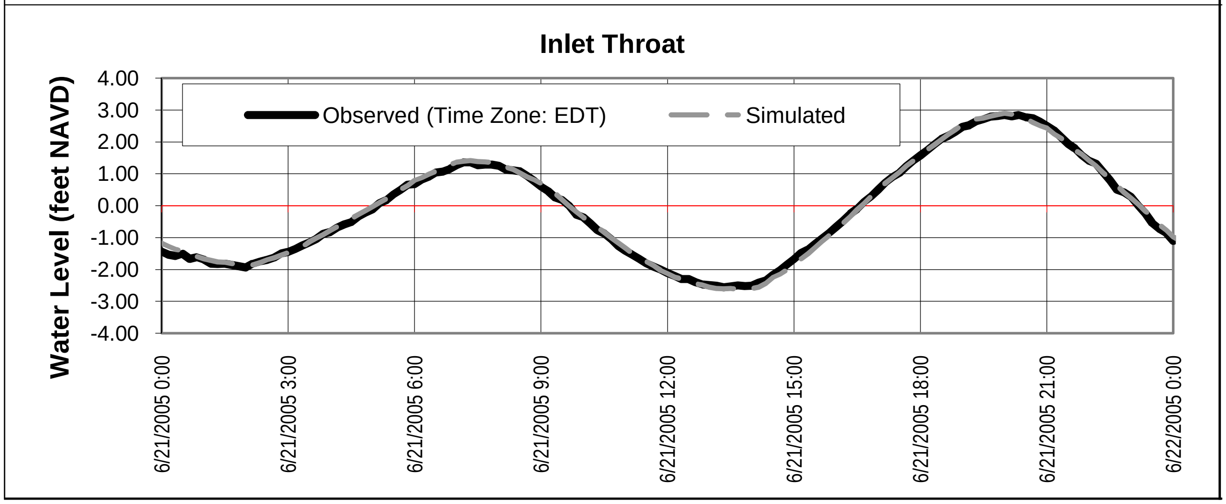




**FIGURE 11-24: Figure Eight Island Flow Calibration, Inlet Throat & Channel Tide Gage Comparisons.**

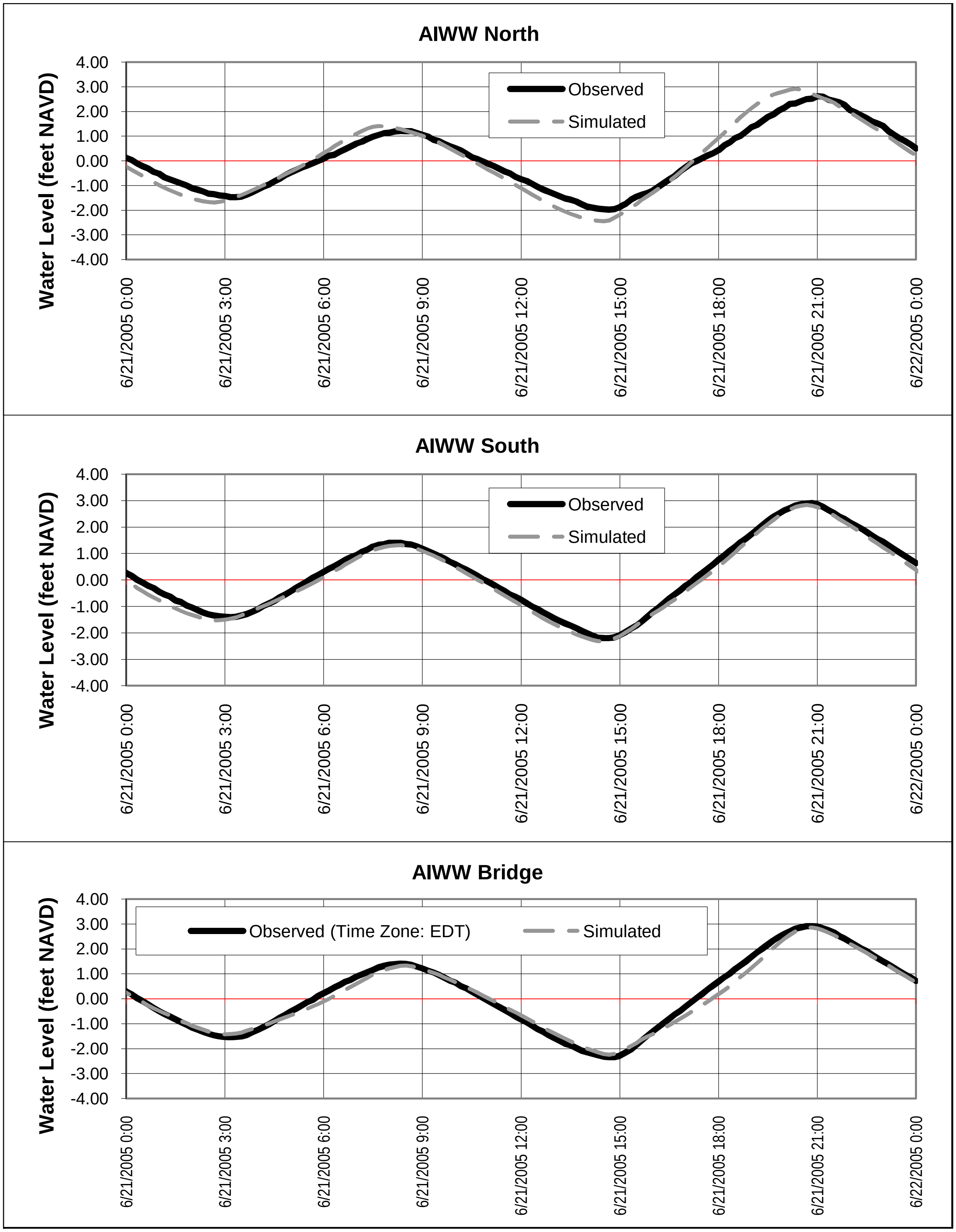



**FIGURE 11-25: Figure Eight Island Flow Calibration,**
**Atlantic Intracoastal Waterway Tide Gage Comparisons.**

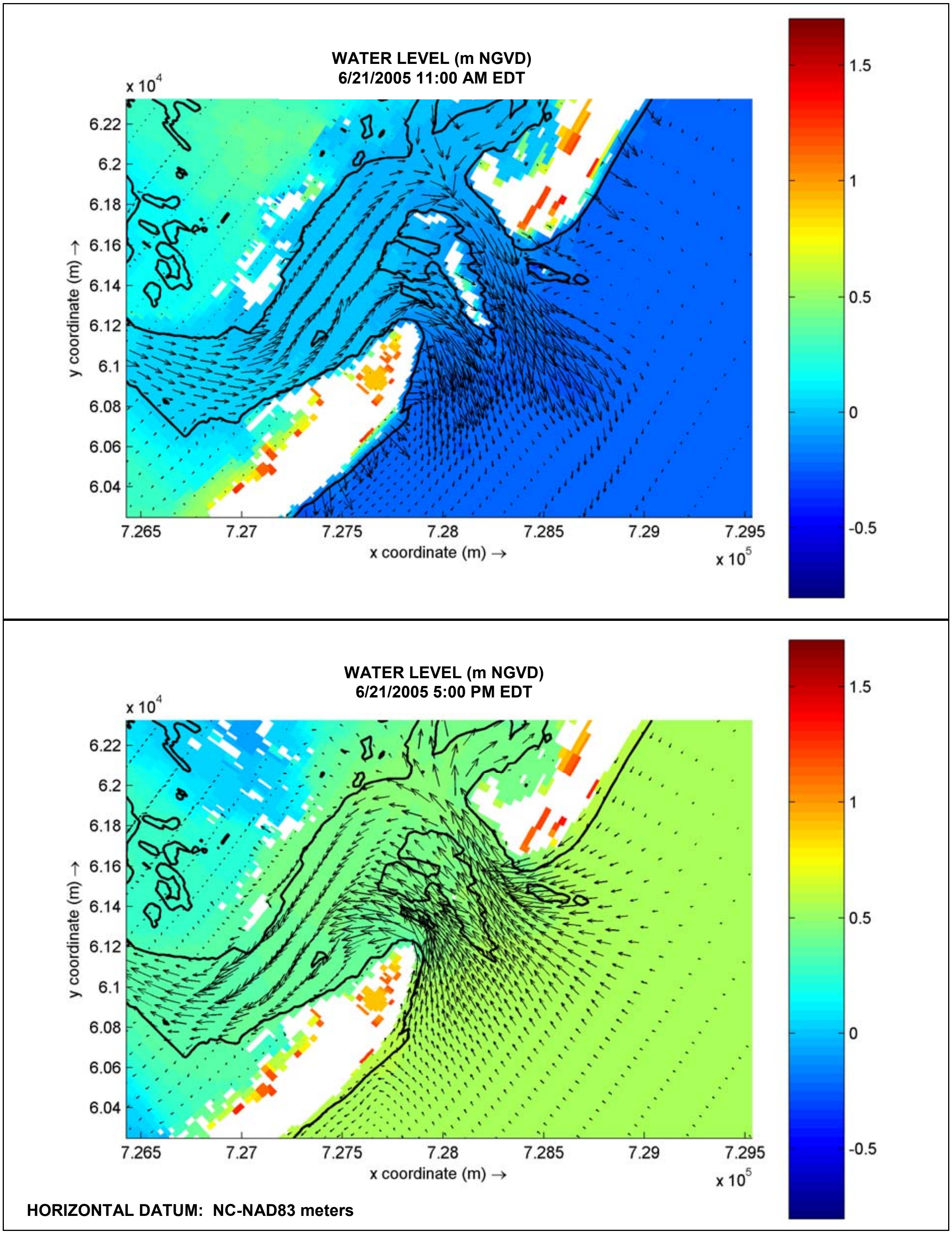



**FIGURE 11-26: Typical Water Levels during Spring Tides.**

Model results during neap tides on June 13, 2005 were used to verify the model (Figures 11-27 to 11-30). During neap tides, the simulated water levels agreed very well with the observed water levels. Thus, the flow model was able to predict the water levels during both neap tides and spring tides with a high level of confidence (see Table 11-2). Given the overall results from the calibration and verification periods, the flow model provided a sufficient description of the flow patterns in Rich Inlet. Accordingly, the remaining model runs in this study utilized the Delft3DFLOW model with the bottom friction values in Figure 11-19.

**TABLE 11-2**

**DELFT3D CURRENT AND WATER LEVEL CALIBRATION & VERIFICATION SUMMARY**

| ADCP | Mean Error (feet/second) | RMS Error (feet/second) |
|---|---|---|
| Currents, June 21, 2005 6:30 am EDT to June 21, 2005, 9:40 pm EDT: | | |
| Inlet Throat | 0.32 | 0.59 |
| Nixon Channel | -0.04 | 0.35 |
| Green Channel | 0.28 | 1.03 |
| **Tide Gage** | **Mean Error (feet)** | **RMS Error (feet)** |
| Water Levels, May 25, 2005, 10:10 am EDT to June 30, 2005, 8:00 pm EDT: | | |
| Green Channel | 0.16 | 0.26 |
| Nixon Channel | -0.02 | 0.19 |
| Inlet Throat | -0.08 | 0.18 |
| AIWW North | -0.04 | 0.28 |
| AIWW South | -0.12 | 0.20 |
| AIWW Middle | -0.10 | 0.20 |
| AIWW Bridge | -0.05 | 0.23 |

## 11.3 Erosion and Deposition Calibration

Sediment transport, erosion, and deposition in the Delft3D modeling package were simulated using Delft3DFLOW. The calibration of sediment transport, erosion, and deposition was based on the volume changes between April 2005 and the present. Parameters examined during the calibration included the following:

- The approximation of the tides.
- The delineation of the wave cases.
- The use of wind stress in both Delft3DFLOW and SWAN.
- The sediment transport parameters within Delft3DFLOW.

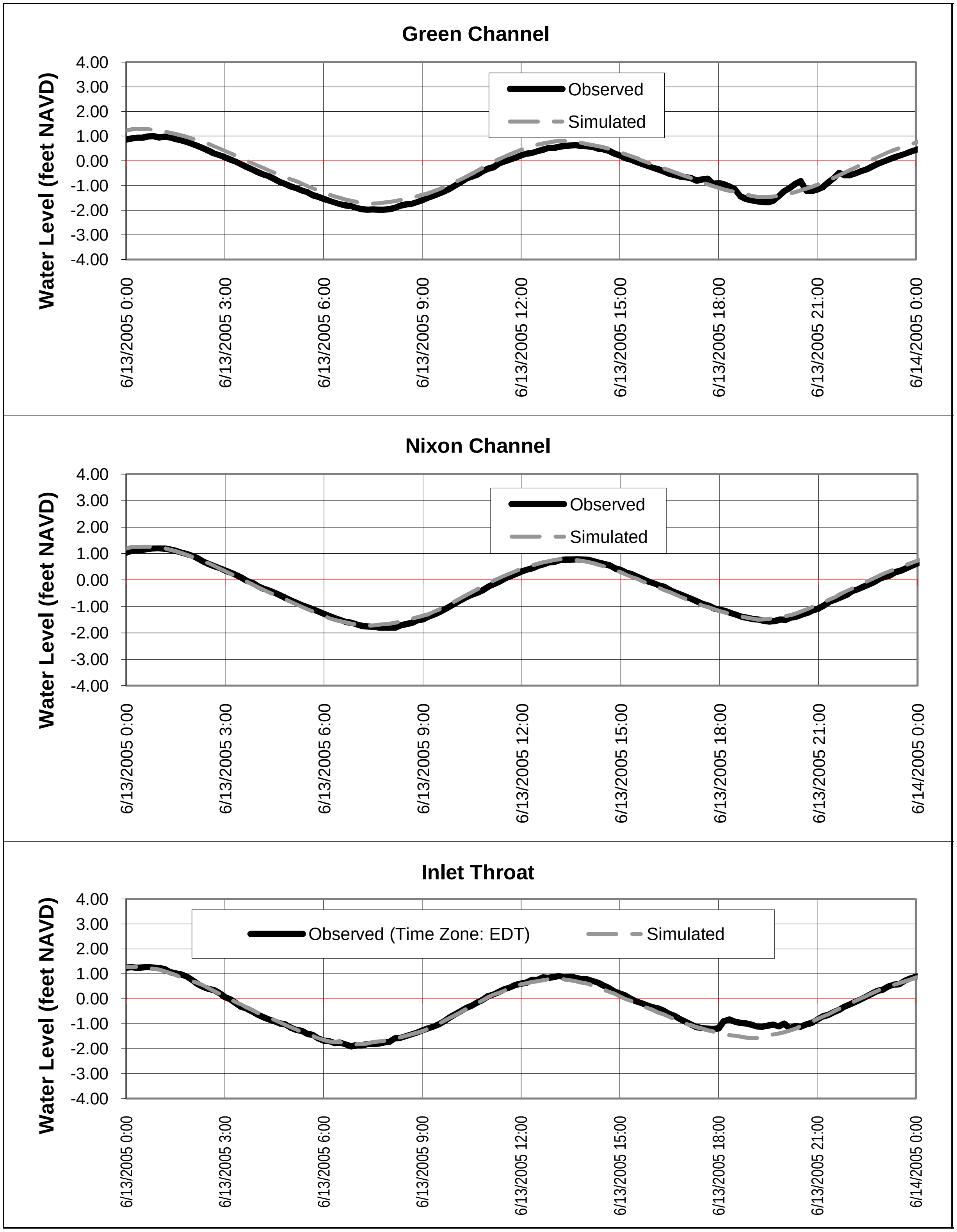



**FIGURE 11-27: Figure Eight Island Flow Verification, Inlet Throat & Channel Tide Gages.**

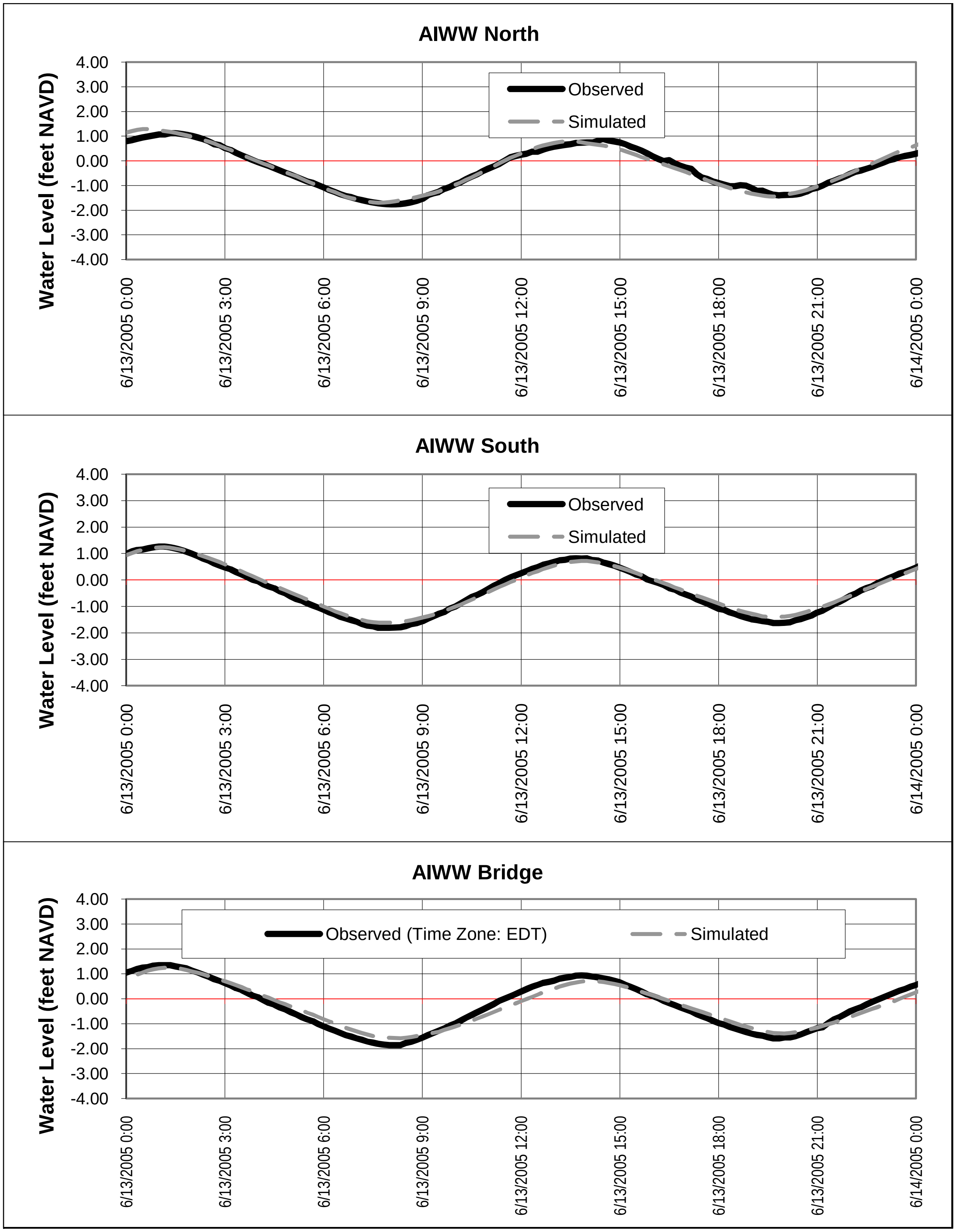



**FIGURE 11-28: Figure Eight Island Flow Verification, Atlantic Intracoastal Waterway Tide Gages.**

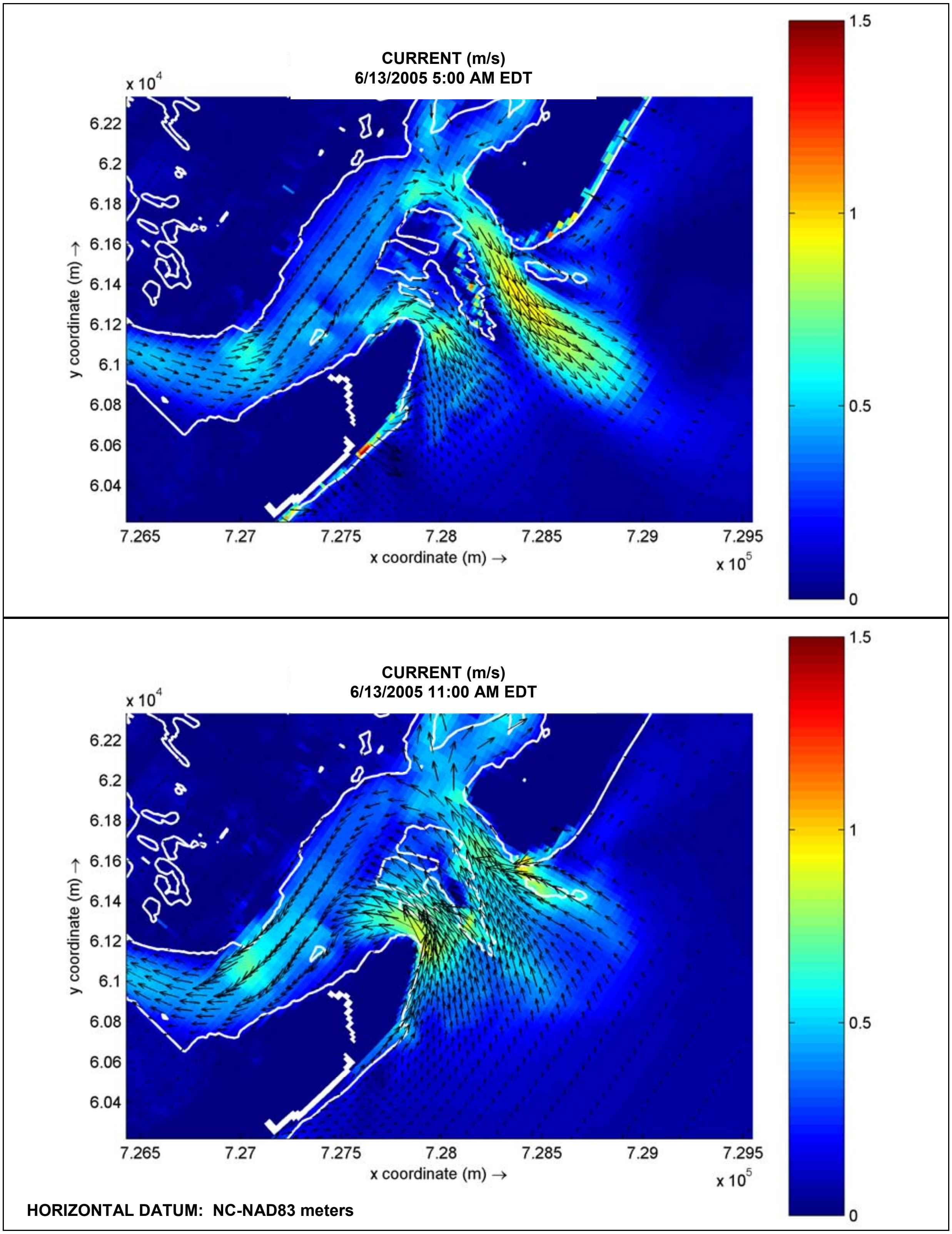



**FIGURE 11-29: Typical Simulated Currents during Neap Tides.**

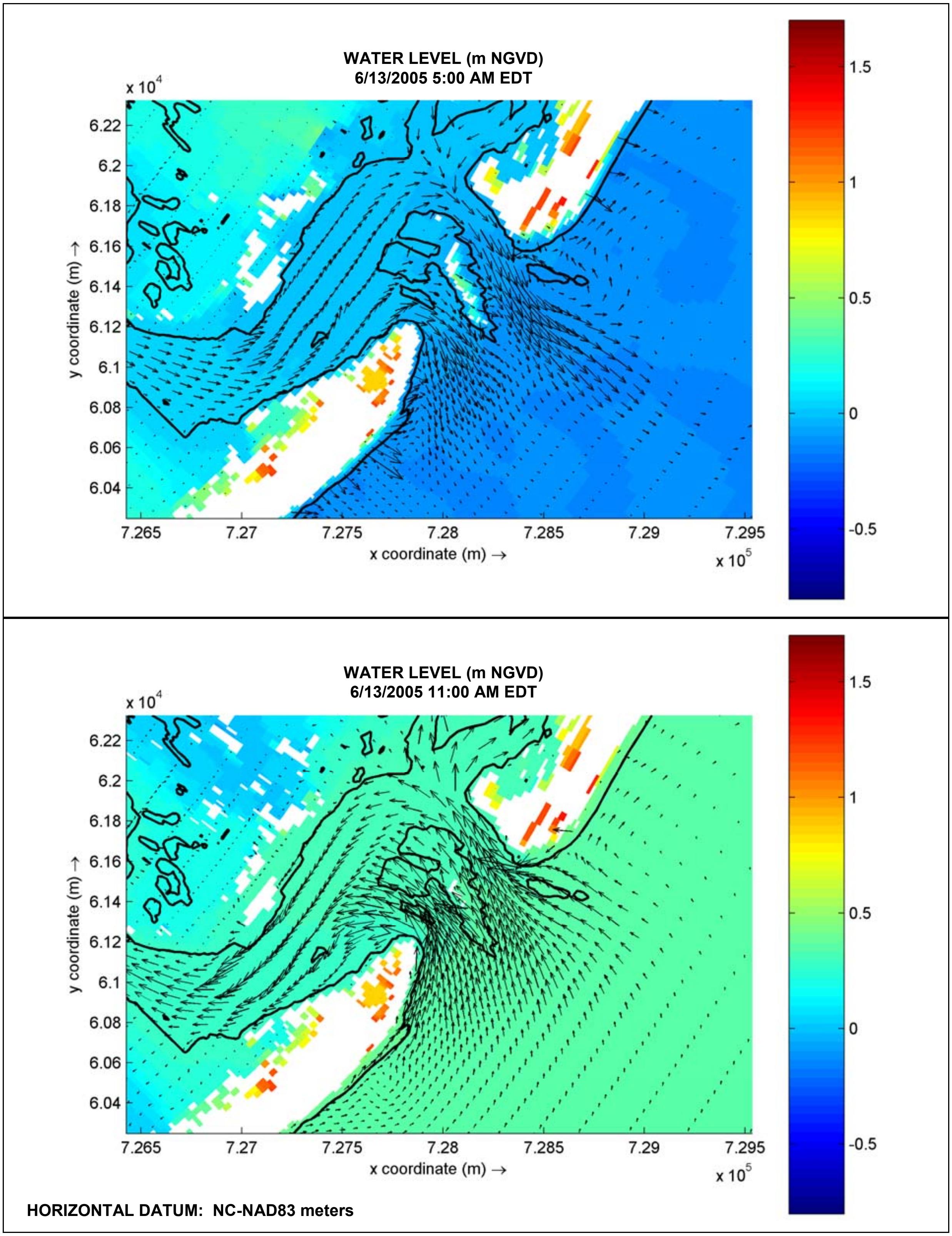



**FIGURE 11-30: Typical Water Levels during Neap Tides.**

### 11.3.1 Tides

Ideally, 2-5 years of bathymetric changes could be simulated using a 2-5 year model run. However, a 2-5 year model run using Delft3DFLOW would require 2-3 months of computational time, even under the best circumstances. To reduce the amount of computational time, a number of methods have been developed so that 5 years of bathymetric changes can be simulated using a 3-7 week model run, which can be completed in 2-7 days.

The first of these methods is the simplification of the tides. As long as a simplified tide with single harmonic produces the same residual transport as 14-15 days of predicted tides, the spring-neap tidal cycle can be approximated using a simplified tide:

$$\eta \approx \eta_o + A\cos(2\pi t/T)$$

where

$\eta$ = water level
$\eta_o$ = mean tide level
$A$ = tidal amplitude
$t$ = time
$T$ = tidal period

To select the best simplified tide, several simulations were conducted using two methodologies (see Table 11-3):

- The Lesser (2009) approach using M2 and C1 tidal harmonics (M2C1 in Table 11-3).
- The mean tidal amplitude ± 20% and the M2 tidal period of 745 minutes (12.42 hours).

**TABLE 11-3**

**SIMPLIFIED TIDE SCHEMES TESTED**

| Tide scheme | Amplitude (feet) | Period (min) |
|---|---|---|
| M2C1 | 2.16 | 1490 |
| M2C1 (-20%) | 1.72 | 1490 |
| M2C1 (+20%) | 2.59 | 1490 |
| Mean | 2.07 | 745 |
| Mean (-20%) | 1.66 | 745 |
| Mean (+20%) | 2.48 | 745 |

The first simulation consisted of 15 days predicted tides based on the harmonics in Table 11-4. The remaining simulations consisted of 15 days of simplified tides characterized a single amplitude and tidal period. Waves were neglected during these simulations, and default sediment transport parameters were utilized.

**TABLE 11-4**

**TIDAL CONSTITUENTS BASED ON WATER LEVEL MEASUREMENTS TAKEN IN THE INLET THROAT, MAY 25 – JULY 7, 2005**

| | Period (hours) | Amplitude (feet) | Phase (degrees) |
|---|---|---|---|
| M2 | 12.42 | 1.77 | 244.1 |
| N2 | 12.66 | 0.41 | 243.4 |
| K1 | 23.93 | 0.40 | 116.3 |
| O1 | 25.82 | 0.18 | 147.9 |
| S2 | 12.00 | 0.17 | 254.6 |
| MM | 661.31 | 0.14 | 331.9 |
| MSF | 354.37 | 0.13 | 290.0 |
| M4 | 6.21 | 0.07 | 148.9 |
| MU2 | 12.87 | 0.07 | 163.9 |
| Q1 | 26.87 | 0.06 | 172.5 |
| L2 | 12.19 | 0.04 | 215.6 |
| MS4 | 6.10 | 0.04 | 214.7 |
| M6 | 4.14 | 0.03 | 53.1 |
| M3 | 8.28 | 0.03 | 190.0 |
| MN4 | 6.27 | 0.03 | 75.7 |
| NO1 | 24.83 | 0.02 | 170.7 |
| 2MN6 | 4.17 | 0.02 | 61.0 |
| SN4 | 6.16 | 0.02 | 63.0 |

Although all 6 tidal schemes in Table 11-3 were tested, tides along the regional are semi-diurnal (see Figures 11-20, 11-21, 11-22, 11-24, 11-25, 11-27, and 11-28). Accordingly, the results of the M2C1 tests are not shown. Test results based on the 745 minute tidal schemes appear in Figures 11-30 to 11-34. The best results were achieved using the mean tidal amplitude of 2.07 feet and a tidal period of 745 minutes (12.42 hours). As shown in Figure 11-34, differences in sedimentation patterns between 15 days predicted tides and 15 days simplified tides (T = 745 minutes, A = 2.07') were small (± 1 foot) or negligible.

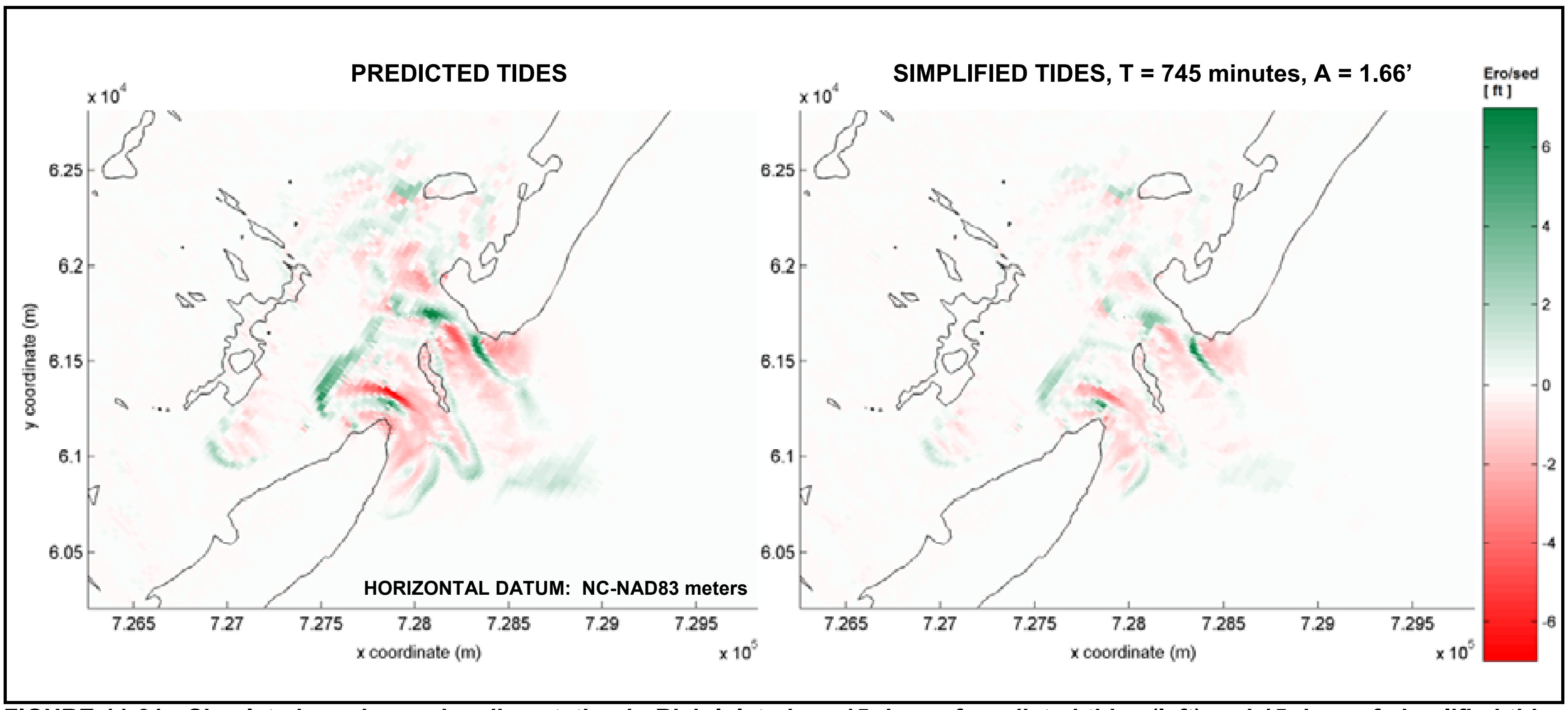



FIGURE 11-31: Simulated erosion and sedimentation in Rich Inlet given 15 days of predicted tides (left) and 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 1.66' (mean – 20%) (right).

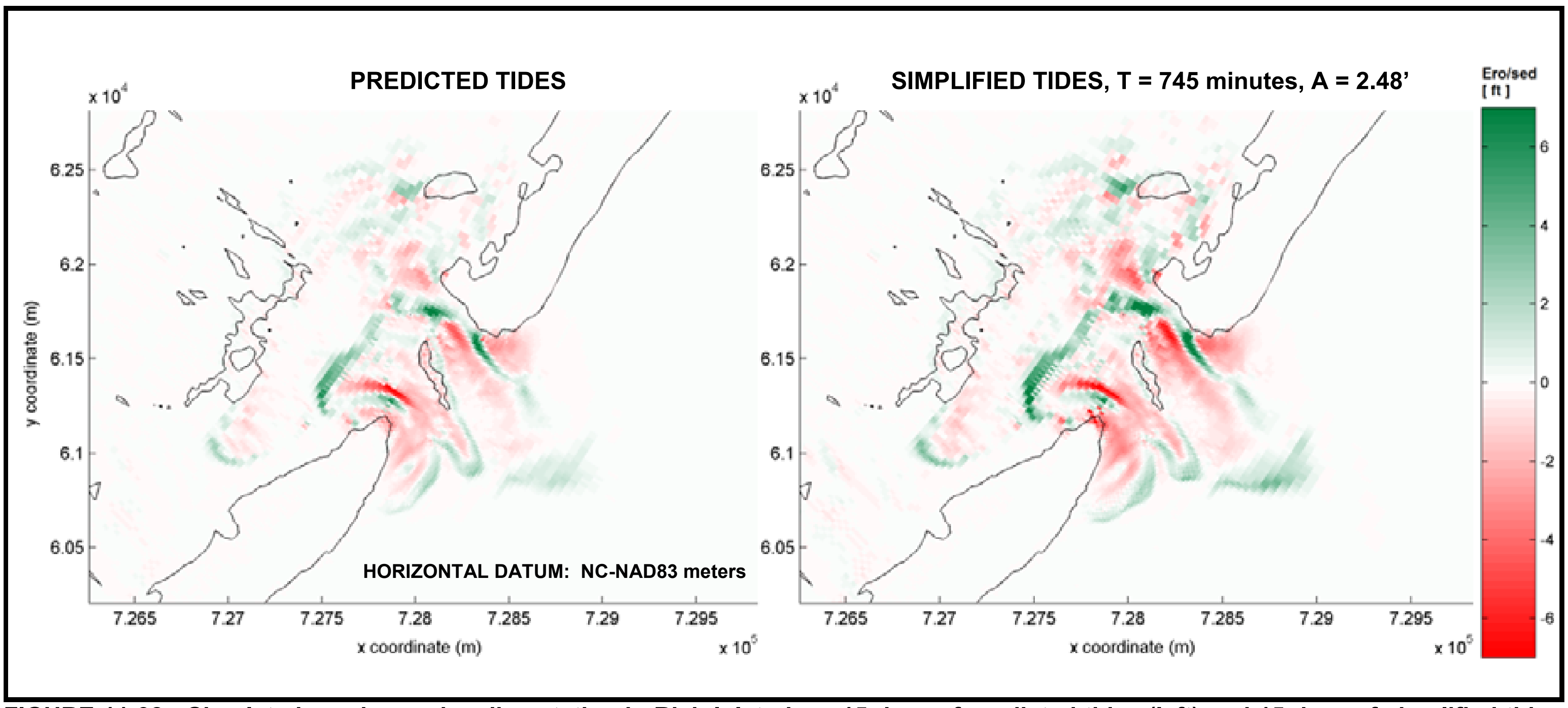



FIGURE 11-32: Simulated erosion and sedimentation in Rich Inlet given 15 days of predicted tides (left) and 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 2.48' (mean + 20%) (right).

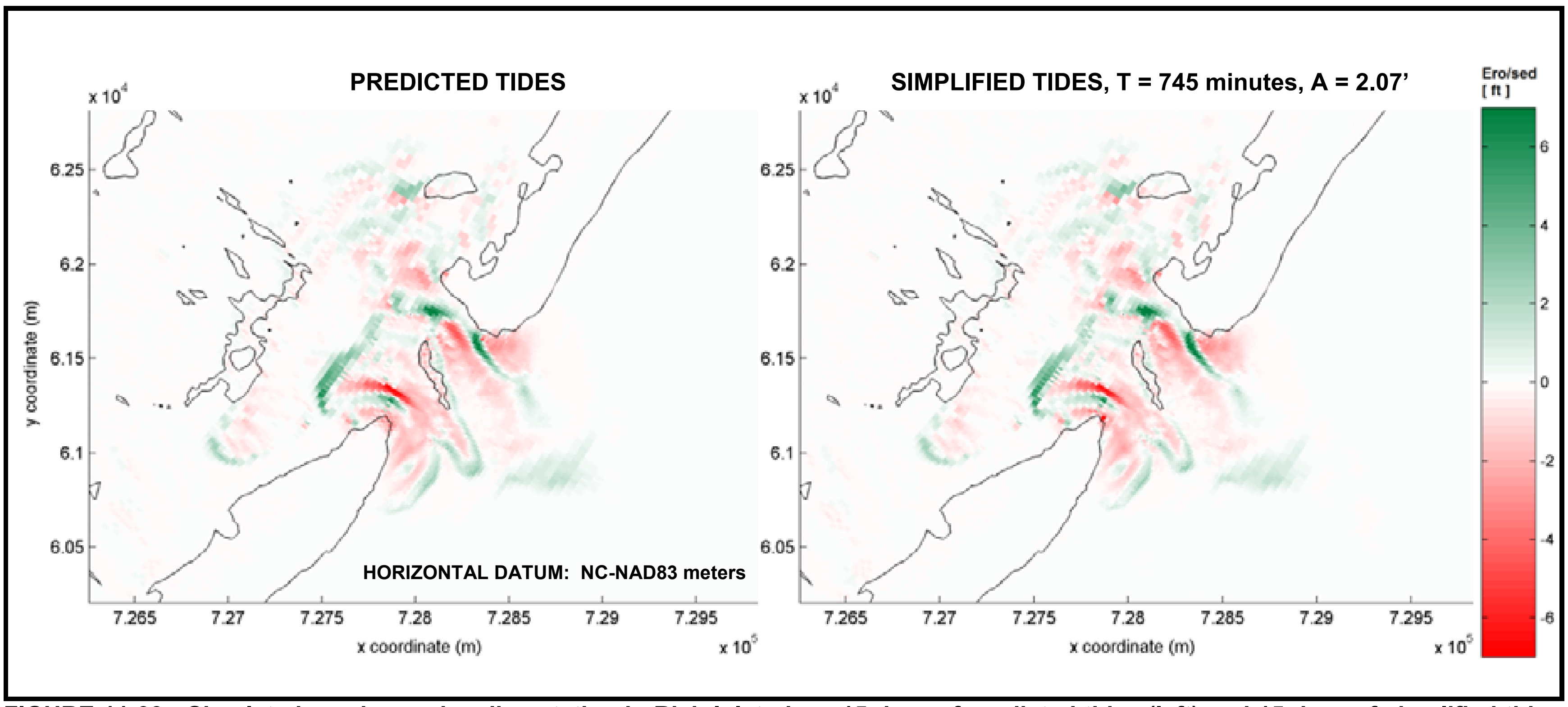



FIGURE 11-33: Simulated erosion and sedimentation in Rich Inlet given 15 days of predicted tides (left) and 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 2.07' (mean) (right).

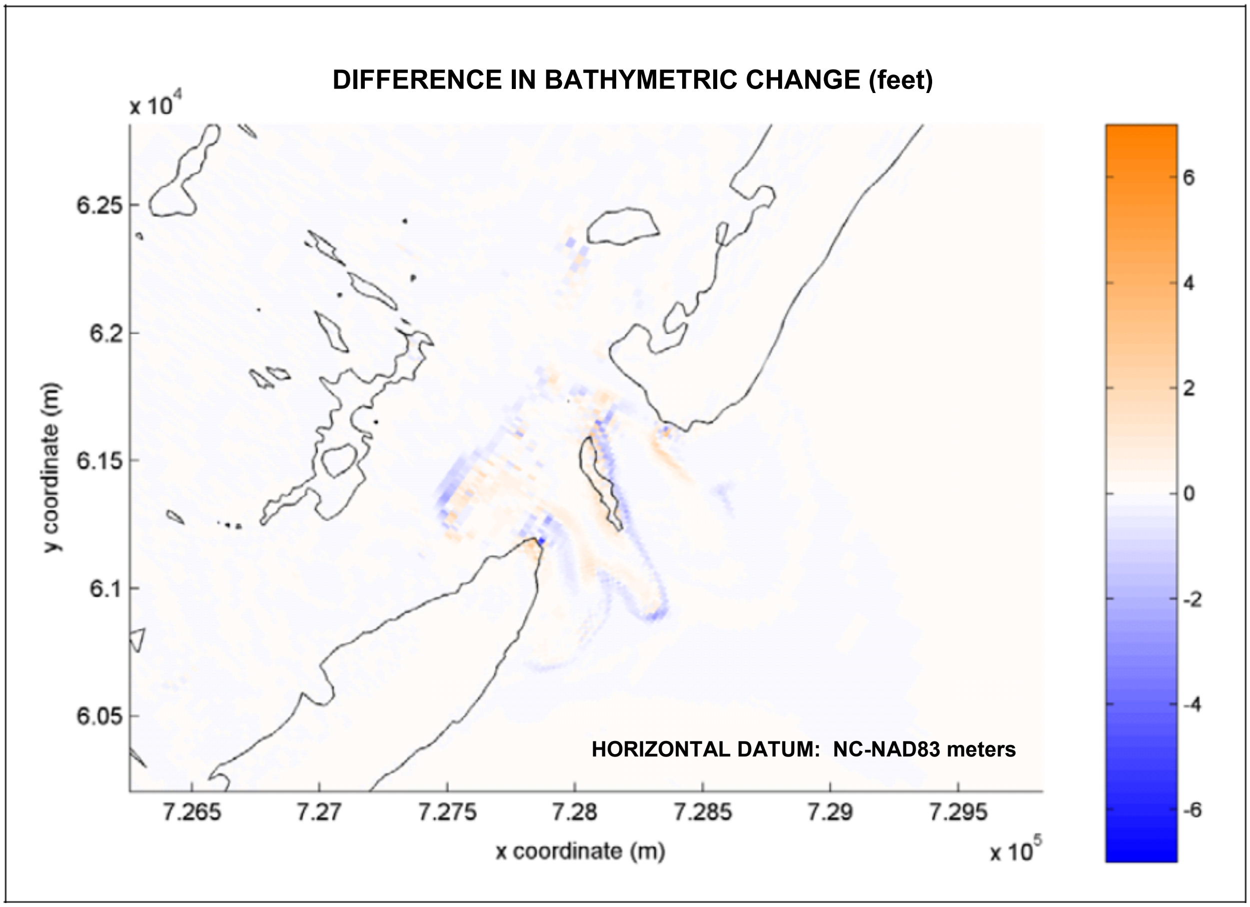



**FIGURE 11-34: Differences in bathymetric change given 15 days of predicted tides versus 15 days of simplified tides assuming T = 745 minutes (12.42 hours) and A = 2.07' (mean). A difference of zero indicates that simplified tides lead to the same bathymetric changes as the predicted tides.**

### 11.3.2 Wave Cases

The waves used to calibrate sediment transport, erosion, and deposition were based on the NOAA Global Wavewatch forecast at 34.00ºN, 76.25ºW (see Figure 11-12). The depth at site was approximately -644 feet NAVD. As noted earlier, it is not practical to simulate 2-5 years of bathymetric changes using a 2-5 year time series of offshore water levels and waves to drive the model. Instead, the Delft3D model is typically run for a shorter period of time, using 10-75 representative wave cases to approximate the general wave climate during the period of interest (i.e.: Lesser, et al., 2004; Benedet and List, 2008).

Potential wave climates for the project area were based on the forecast wave record at 34.00°N, 76.25°W between October 1999 and April 2007. All waves propagating from the landward direction bands (200° to 360° and 0° to 55°) were ignored, along with all waves smaller than 1.64 feet (0.5 m). The remaining wave records were divided into wave height and direction classes, with each wave class containing an equal amount of wave energy (in KW-Hours/m). This method, known as the Energy Flux Method, characterized each wave record based on the energy flux:

$E_p \approx 1.56\ T_p \rho g H_s^2 / 2$ (deep water assumption)

$\text{Energy} = E_p \Delta t$

Where

$E_p$ = energy flux
$T_p$ = peak wave period
$\rho$ = sea water density (1025 $kg/m^3$)
$g$ = gravitational acceleration (9.81 $m/s^2$)
$H_s$ = significant wave height
$\Delta t$ = interval between wave records (3 hours)

To simulate 1 year of sediment transport, erosion, and deposition, each wave case was run for 1 to 3 tidal cycles per year, which were characterized by a single harmonic (see previous section). Sediment transport values were then scaled by a Morphological Acceleration Factor, so that 1 to 8 weeks of the simulation would be equivalent to 1 year of erosion (i.e.: Lesser, et al., 2004; Benedet and List, 2008):

$M = T_{study\ period} / T_{model\ period}$

where

M = Morphological Acceleration Factor
$T_{study\ period}$ = (length of the study period) x (percent occurrence for each wave case)
$T_{model\ period}$ = duration of the wave case in the model simulation

Lower M values were used for the higher waves, during which the majority of the significant bathymetric changes occurred. Conversely, higher M values were used for the more frequent, but smaller waves. This schematization was consistent with the standard practices used within the Delft3D modeling community.

Based on the method above, 3 wave climates were delineated:

1. A 12-case wave climate.
2. A 20-case wave climate.
3. A 70-case wave climate that approximated the full time series of waves between October 1999 and April 2007.

To determine which wave climate would be the most appropriate, preliminary Delft3D-FLOW simulations using each wave climate were performed. Since the objective of this task was to determine how many wave cases would be necessary, sediment transport was activated within the Delft3D model, but changes to the seafloor elevation were not. Default sediment transport parameters were also utilized. These settings ensured that the sediment transport rates from each wave climate would not be biased by the erosion or deposition that would theoretically occur during the various wave cases. Average longshore sediment transport values were then extracted from the output of each simulation. Finally, sediment transport values based on the first two wave climates were compared to those of the 70-case wave climate (Figure 11-35).

Since erosion and deposition were not considered in this task, the results in Figure 11-35 were not intended to be compared to the sediment budgets in Figures 8-4 or 8-5. However, the results of the test showed that it would be possible to use a 12-case wave climate in the subsequent phases of the model calibration and the future conditions simulations. Wave cases appear in Table 11-5 and Figure 11-36.

**TABLE 11-5**

**OCTOBER 1999 TO APRIL 2007**
**WAVE CLIMATE**
**34.00ºN, 76.25ºW, -644' NAVD**

| Wave Case | Hs (feet) | Tp (sec.) | Wave Dir. (deg.) | Frequency (days/year) | Tidal Cycles in Model per Year | Morph. Acceler-ation Factor | Wind Speed (mph) | Wind Dir. (deg.) |
|---|---|---|---|---|---|---|---|---|
| #1 | 4.5 | 7.9 | 64.2 | 21.5 | 2 | 20.7 | 3.6 | 77.1 |
| #2 | 8.3 | 9.5 | 63.4 | 5.3 | 1 | 10.2 | 8.7 | 45.0 |
| #3 | 11.8 | 10.2 | 63.6 | 2.4 | 1 | 4.6 | 19.9 | 45.0 |
| #4 | 3.6 | 8.0 | 91.3 | 32.6 | 2 | 31.5 | 2.5 | 120.3 |
| #5 | 6.0 | 8.5 | 89.1 | 11.1 | 1 | 21.5 | 6.1 | 61.7 |
| #6 | 10.0 | 9.2 | 85.7 | 3.6 | 1 | 7.0 | 9.2 | 15.0 |
| #7 | 3.2 | 7.5 | 122.1 | 44.7 | 3 | 28.8 | 4.0 | 166.4 |
| #8 | 7.0 | 7.5 | 128.5 | 9.2 | 1 | 17.8 | 5.6 | 147.4 |
| #9 | 14.7 | 9.5 | 130.9 | 1.6 | 1 | 3.2 | 4.7 | 155.4 |
| #10 | 4.5 | 5.4 | 181.7 | 30.3 | 2 | 29.3 | 8.4 | 206.9 |
| #11 | 8.4 | 7.0 | 177.8 | 6.6 | 1 | 12.8 | 13.9 | 232.2 |
| #12 | 13.4 | 8.2 | 178.7 | 2.2 | 1 | 4.3 | 18.3 | 240.2 |

The smallest wave cases have heights in the range of 3.2 feet (1 m). The intermediate wave heights are in the range of 7.5 feet (2.3 m), and the highest waves are in the 12.5 foot (3.8 m) range. Peak wave periods vary from 5.4 to 10.1 seconds, and the wave direction varies from 63 to 181 degrees. The wind associated to the representative wave conditions was defined as the mean wind of each wave class (selected by Energy Flux Method). Each repetition of the 12 wave cases corresponded to 1 year of sediment transport, erosion, and deposition.

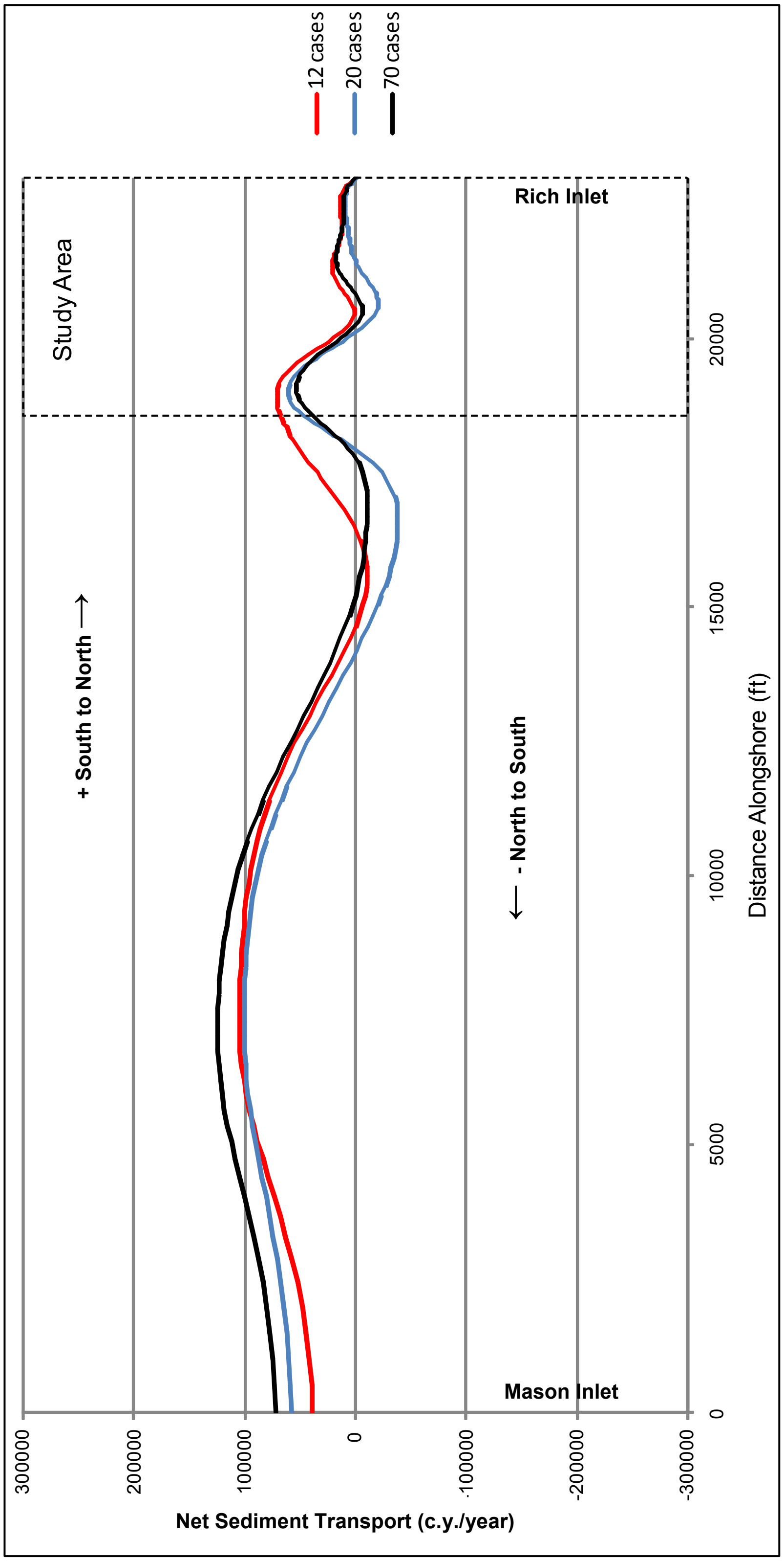



**FIGURE 11-35: Theoretical Longshore Sediment Transport along Figure Eight Island Based on Wave Climates with 12, 20, and 70 Cases.**

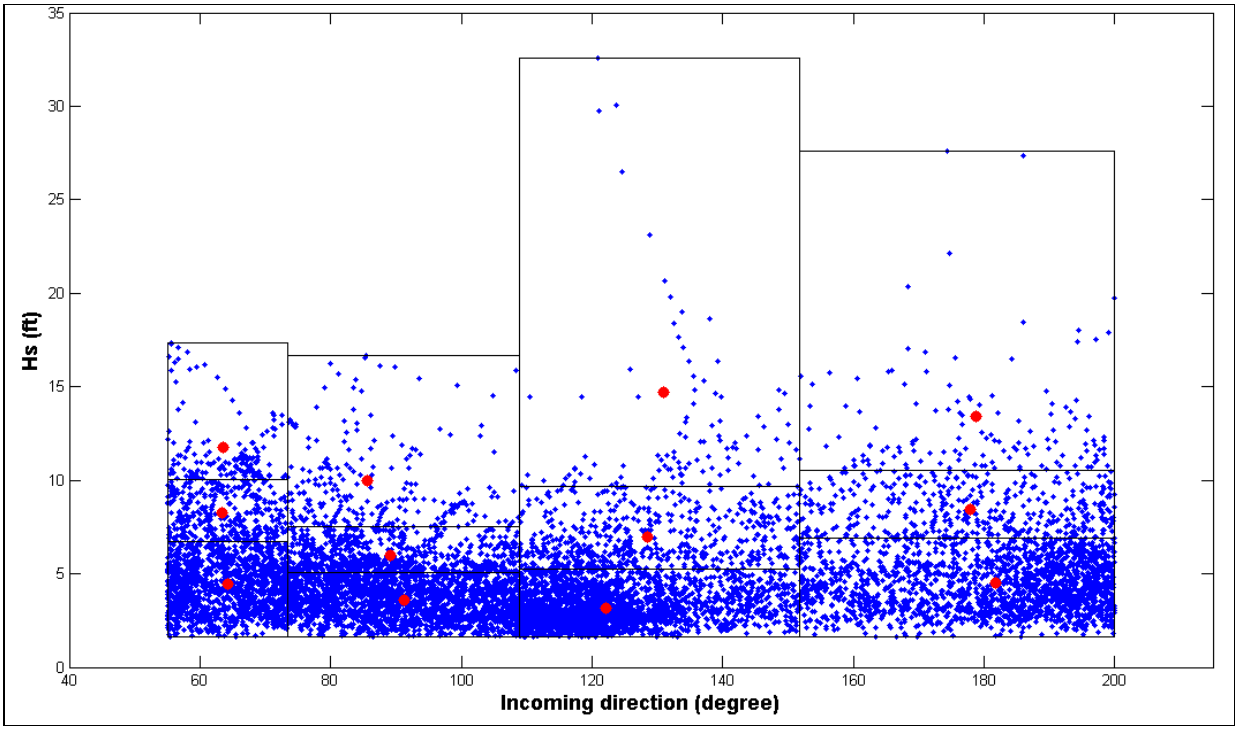



**FIGURE 11-36: October 1999 To April 2007 Wave Climate, 34.00ºN, 76.25ºW, -644' NAVD, with Representative Wave Cases (red) for 12 Wave Classes (black squares).**

### 11.3.3 Wind Stress

Both the SWAN and Delft3DFLOW models utilize wind stress formulations. In SWAN, wind stress governs the growth and generation of waves within the model grids. In Delft3DFLOW, shear stresses due to wind can be activated to partially govern the currents.

A large number of simulations were conducted how the model would perform if wind stress were:

1. Neglected in both models.
2. Considered in the Delft3DFLOW model but neglected in the SWAN model.
3. Considered in the SWAN model but neglected in the Delft3DFLOW model.
4. Considered In both models.

In each simulation, bathymetric changes were activated within Delft3DFLOW.

Sediment transport estimates given the first scenario were similar to those in Figure 11-35, which predicted net sediment transport towards the north along most of the island. While this was consistent with the two sediment budgets (Figures 8-5 and 8-4) at Rich Inlet, it was not consistent with the two sediment budgets elsewhere. Net sediment transport estimates under the second and third scenario appear in Figure 11-37. Similar to the first scenario, the direction of the net sediment transport was not consistent with the two sediment budgets. However, when

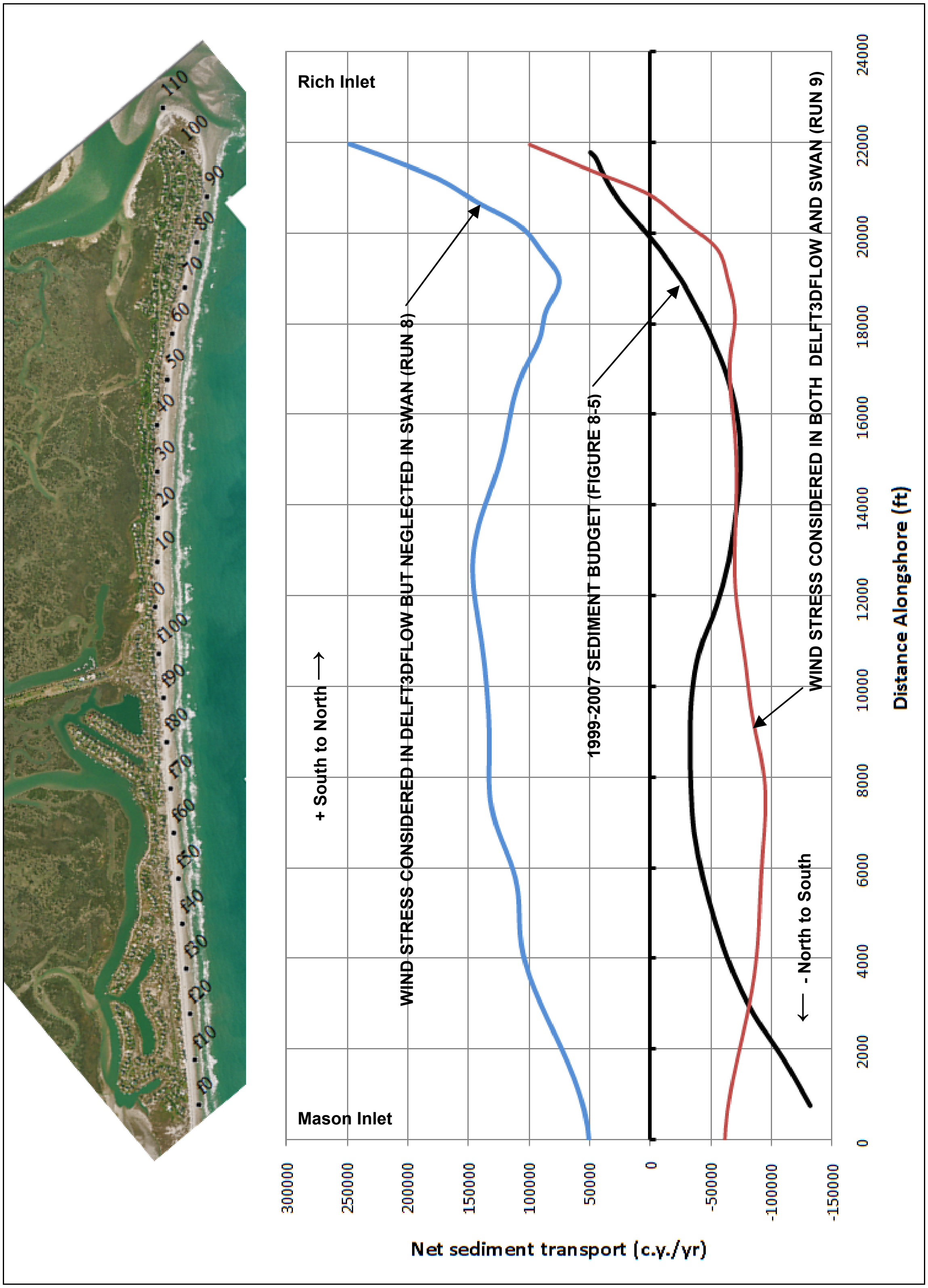



**FIGURE 11-37: Sensitivity of Net Sediment Transport to the Activation of Wind Stress in Delft3DFLOW and SWAN.**

wind stress was activated within both SWAN and Delft3DFLOW, the simulated sediment transport was closer to the 1999-2007 sediment budget. Subsequent simulations found that wind stress was not a critical factor in the Delft3DFLOW model, even though its application was necessary in the SWAN model. Accordingly, the final calibration run (not shown in Figure 11-37) utilized wind stress in the SWAN model but neglected wind stress in the Delft3DFLOW model. The results of the final calibration run are discussed in the next section.

### 11.3.4 Sediment Transport Parameters and Other Model Settings

The final phase of the calibration process considered the various sediment transport parameters in the model, along with the sequencing of the wave cases, the time step, the grid spacing, and other model settings. Over 40 calibration runs were performed during this phase. The final calibration run utilized the April 2005 survey as the primary bathymetric data source for the initial conditions, followed by the other data sources listed in Section 11.2.1. Grids were identical to those used in Figures 11-10 and 11-11. The duration of the model run was from April 2005 to April 2012.

A comparison of the simulated and observed volume changes on Figure Eight Island between April 2005 and October 2008 appear in Figure 11-38. Overall, the simulated volume changes are consistent with the observed volume changes. Both indicate a high level of erosion on the north end of the island (Surf Court to Rich Inlet, 70+00 to 110+00), mild erosion between profiles 30+00 and 70+00, and stable beaches between Backfin Point Road (F80+00) and profile 30+00. The model results do not follow the observed changes exactly. However, all of the general erosion patterns along the island's beaches are represented.

On Hutaff Island, the volume changes between April 2005 and April 2007 were anomalous due to the formation of a swash into Rich Inlet during Hurricane Ophelia in October 2005 (see Section 7.0). Since the 12 wave cases in Table 11-5 did not specifically include a Category 1 hurricane, a direct comparison of the model results to the storm-dominated changes was not appropriate. However, the model results followed the general erosion patterns on Hutaff Island between 1996 and 2000, which were characterized by accretion on the south end of the island (profiles 145+00 to 175+00) and erosion to the north (see Figure 11-39).

Net sediment transport during the final calibration run appears in Figure 11-40. In general, the sediment transport predicted by the model on the north end of Figure Eight Island is consistent with the short-term sediment budget in Figure 8-4.

Based on the results in Figures 11-38 to 11-40, the Delft3DFLOW and SWAN model provide a realistic description of the waves (Figures 11-41 and 11-42), currents (Figures 11-23 and 11-29), and erosion patterns (Figures 11-38 and 11-39) along Figure Eight Island and Hutaff Island. Accordingly, the model setup in Tables 11-5 and 11-6 was adopted to evaluate the various erosion control alternatives in Section 9.0.

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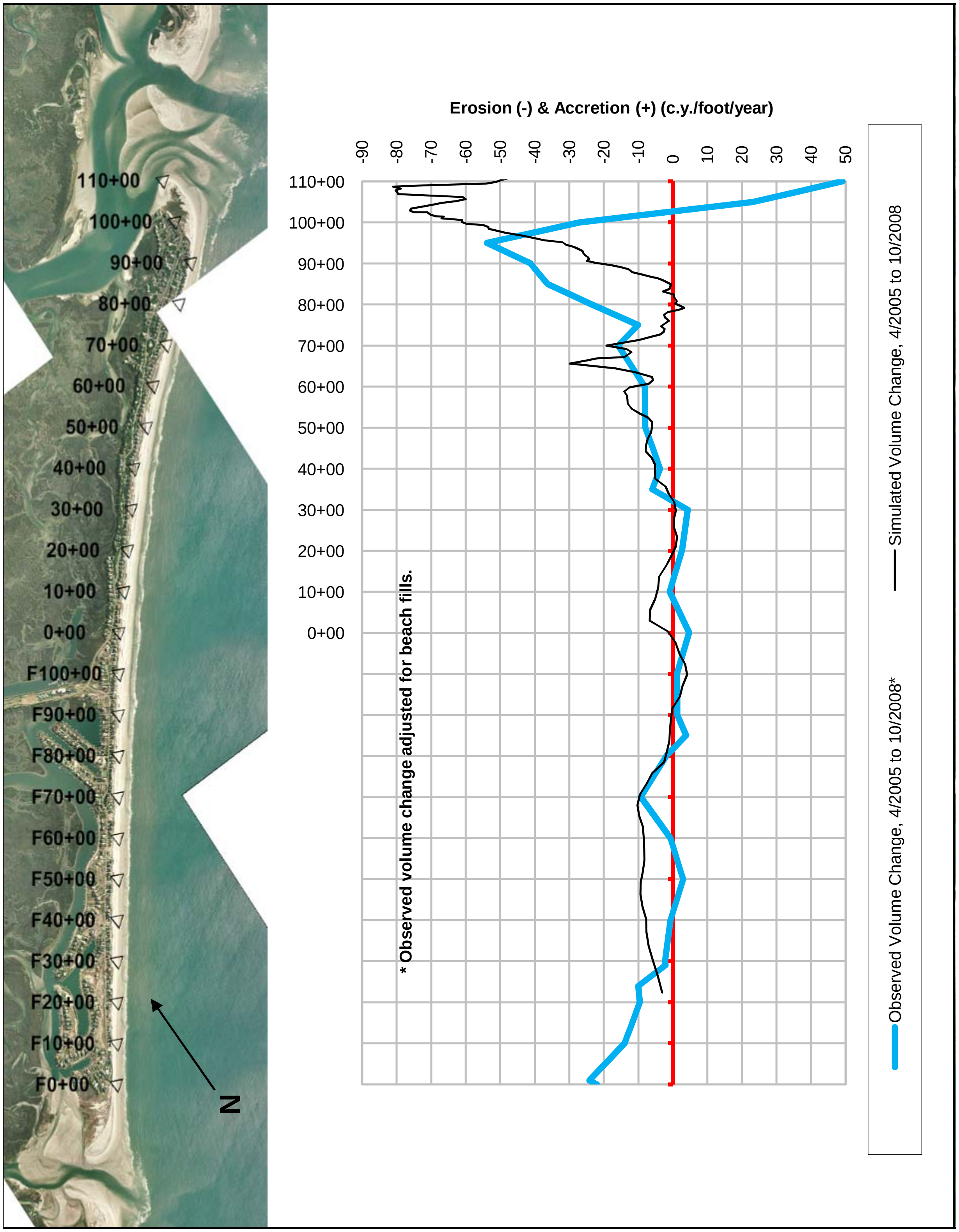


**FIGURE 11-38: Delft3D Erosion & Deposition Calibration Results on Figure Eight Island.**

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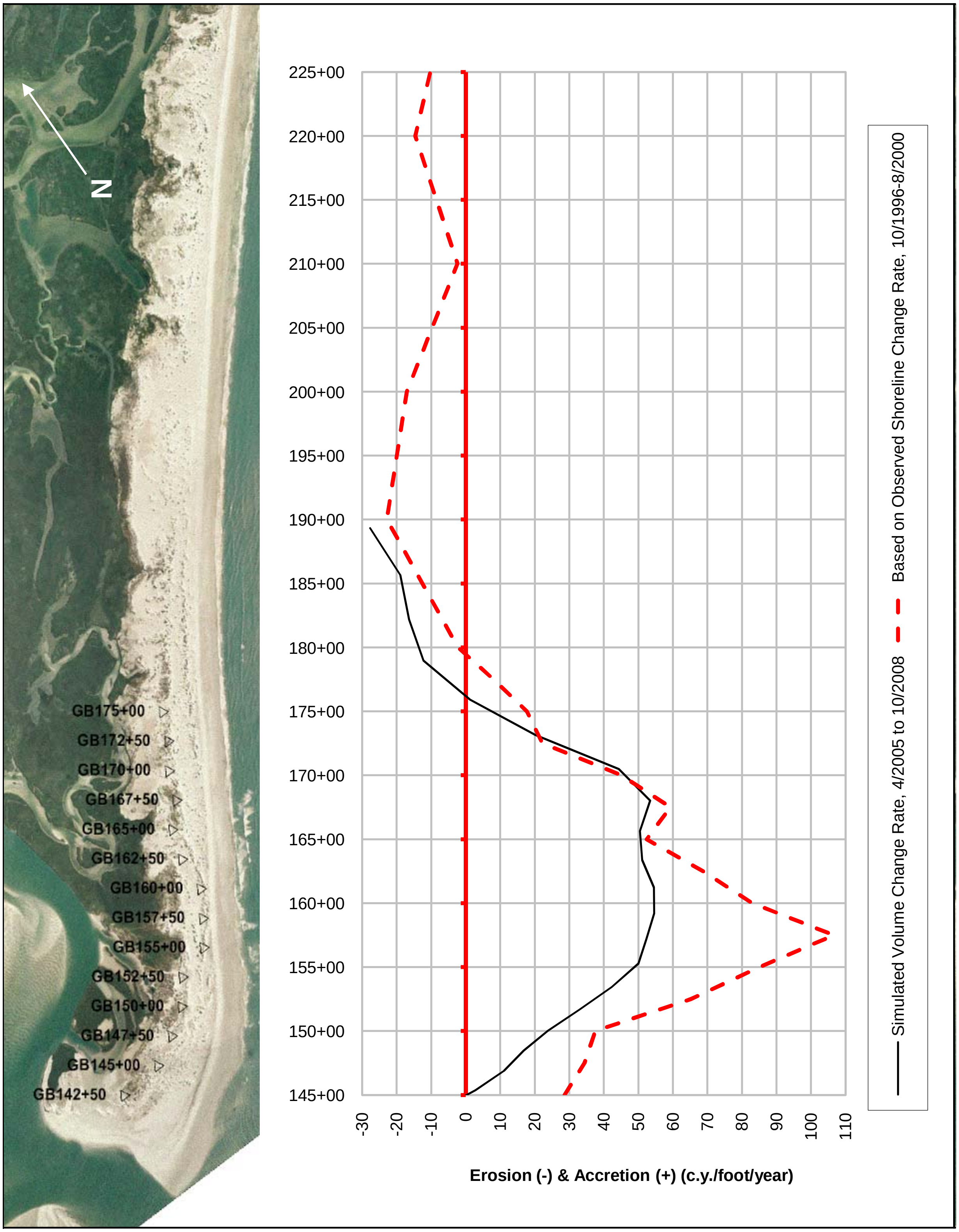


**FIGURE 11-39: Delft3D Erosion & Deposition Calibration Results on Hutaff Island.**


**FIGURE 11-40: Comparison of the Net Longshore Sediment Transport Based on the Final Delft3D Calibration Run and the 2005-2007 Sediment Budget.**

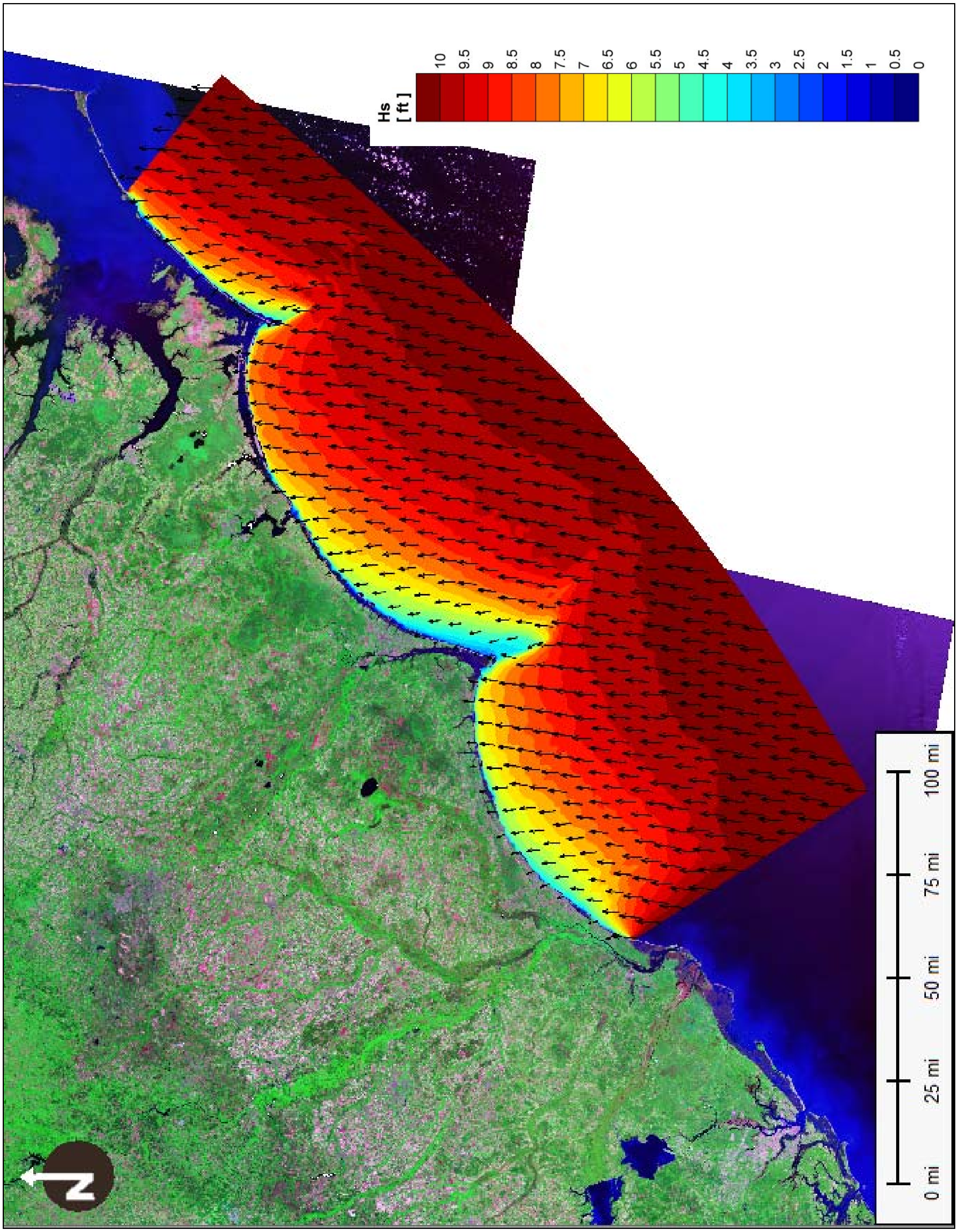


**FIGURE 11-41: Typical Wave Transformation Patterns on the Regional Wave Grid (Offshore Boundary Condition - Hs: 10.3 feet; Tp: 7.3 seconds; Dir: 187 degrees).**

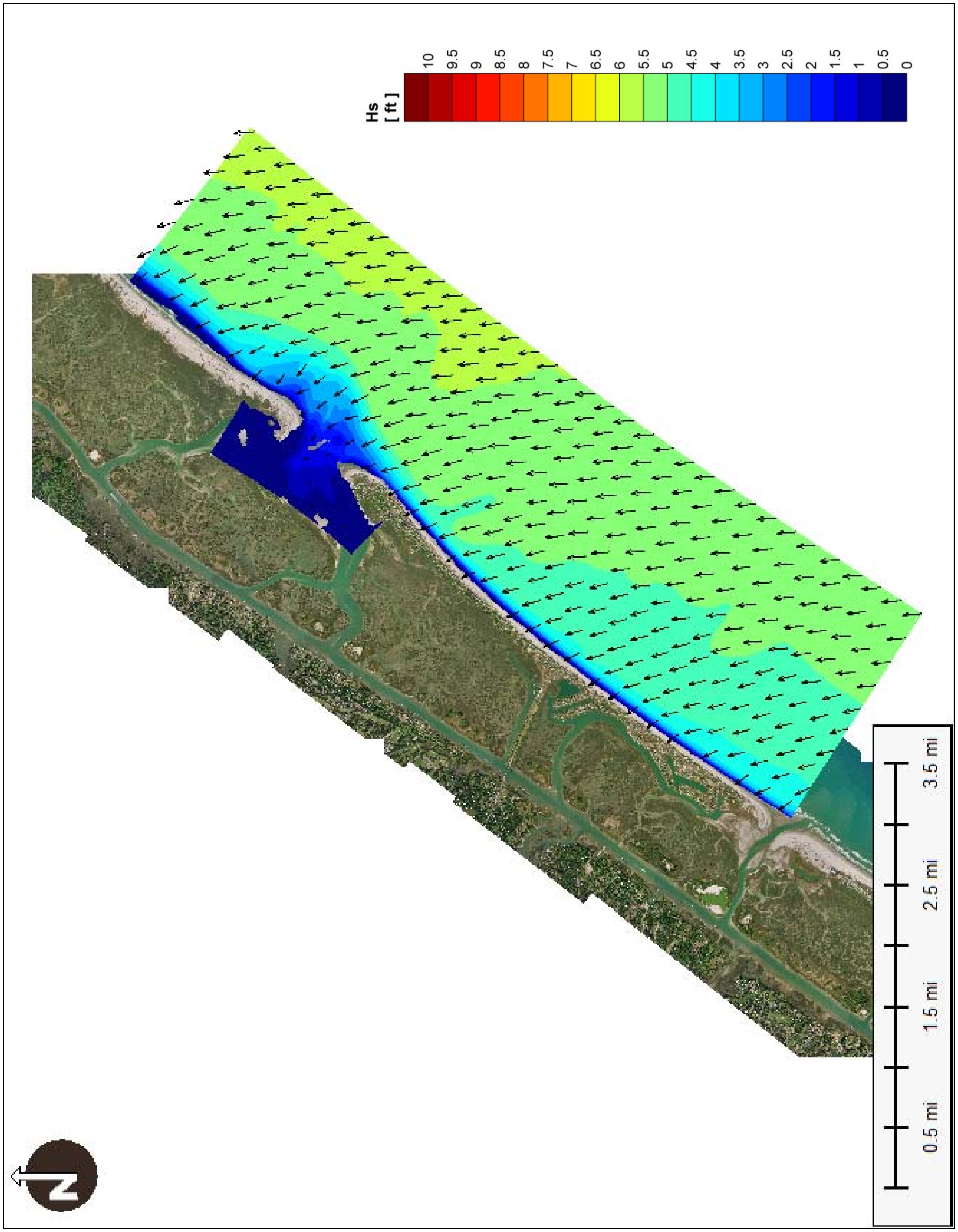


**FIGURE 11-42: Typical Wave Transformation Patterns on the Local Wave Grid (Offshore Boundary Condition - Hs: 10.3 feet; Tp: 7.3 seconds; Dir: 187 degrees).**

**TABLE 11-6**

**DELFT3FLOW AND SWAN MODEL SETUP**
**FIGURE EIGHT ISLAND, NC**

| **SWAN model parameters** | |
|---|---|
| Gravity | 9.81 m/s² (32.2 feet/s²) |
| Water Density | 1025 kg/m³ (64 lbm/foot³) |
| Min. Depth for Computations | 0.05 m (0.16 feet) |
| Spectra Type | JONSWAP |
| Peak Enhancement Factor | 3.3 |
| Directional Space | 0 to 360 deg. |
| Number of Direction Bands | 36 |
| Lowest Frequency | 0.05 hz |
| Highest Frequency | 1 Hz |
| Number of Frequency Bands | 24 |
| Depth Induced Breaking - $\alpha_b$ | 1 |
| Depth Induced breaking – $\gamma$ ($H_b/d_b$) | 0.73 |
| Bottom Friction Roughness Scale | 0.01 m (0.4") |
| Diffraction Smoothing Coefficient | 0.2 |
| Diffraction Smoothing Steps | 5 |
| Frequency Shift | Activated |
| Refraction | Activated |
| Wind growth | Activated |
| Whitecapping | Activated |
| Quadruplets | Activated |
| Percent Accuracy to Accept Iteration | 95% |
| Max. Number of Iterations | 15 |
| **DELFT3DFLOW Hydrodynamic Parameters** | |
| Number of Vertical Layers | 5 |
| Time Step | 30 seconds |
| East Boundary Type | Water level – Harmonic |
| East Boundary Amplitude & Period | 2.17 feet / 745 minutes |
| East Boundary Reflection Parameter $\alpha$ | 0 |
| North Boundary Type | Zero Gradient (Neumann) |
| South Boundary Type | Zero Gradient (Neumann) |
| Gravity | 9.81 m/s² (32.2 feet/s²) |
| Water Density | 1025 kg/m³ (64 lbm/foot³) |
| Roughness Chezy | (see Figure 11-19) |
| Stress Formulation Due To Wave Forces | Fredsoe |
| Horizontal Eddy Viscosity | 5 $m^2/s$ (52 $foot^2/s$) |
| 3-D Turbulence Model | K-Epsilon |
| Advection Scheme For Momentum | Cyclic |
| Advection Scheme For Transport | Cyclic |
| Horizontal Forester Filter | Activated |
| Freshwater Discharges | No |

**TABLE 11-6 (continued)**

**DELFT3FLOW AND SWAN MODEL SETUP**
**FIGURE EIGHT ISLAND, NC**

| DELFT3DFLOW Sediment Transport and Morphology Parameters | |
|---|---|
| Reference Density for Hindered Setting | 1600 kg/m³ (99.9 lbm/foot³) |
| Specific Density | 2650 kg/m³ (165.4 lbm/foot³) |
| Dry Bed Density | 1600 kg/m³ (99.9 lbm/foot³) |
| Median Diameter | 0.3 mm |
| Update Bathymetry During Simulation | Yes |
| Spin Up Period | 725 minutes |
| Min. Depth for Sediment Calculation | 0.1 m (4") |
| VanRijn Reference Height Factor | 1 (2") |
| Threshold Sediment Thickness | 0.05 m |
| Estimated Ripple Height Factor | 2 |
| Dry Cell Erosion Factor (THETSD) | 1 |
| Multiplication Factor For Suspended Sed. Ref. Concentration (SUS) | 1.4 |
| Multiplication Factor For Bed-Load Transport Vector Magnitude (BED) | 0.8 |
| Wave-Related (Orbital Motions) Suspended Sed. Transport Factor (SUSW) | 0.1 |
| Wave-Related (Orbital Motions) Bed-Load Sed. Transport Factor (BEDW) | 0.1 |
| Horizontal Eddy Diffusivity | 2 $m^2/s$ (22 $foot^2/s$) |

## 11.4 Future Conditions

### 11.4.1 Alternative 1 – No Action

Alternative 1 assumes that the present strategies to manage the island's shoreline in Table 6-2 will continue into the future. As shown in Table 6-2, dredging and fill operations around Figure Eight Island are highly variable in terms of timing and quantity, since they are dependent on decisions made by the Association, State agencies, and the Federal government. This sort of uncertainty cannot be incorporated into the Delft3D model. For this reason, Alternative 1 was not simulated.

### 11.4.2 Alternative 2 – Abandon/Retreat

Alternative 2 assumes that there will be no more beach fill, dune maintenance, inlet maintenance, or sand bag placement operations. Accordingly, this alternative is the true "Without-Project" scenario, and is the basis for evaluating the performance and impacts of the other alternatives.

If no beach or inlet maintenance occurs over the next 5 years, the main channel of Rich Inlet will migrate towards the middle of the inlet. As part of this process, the flood channel on the southwestern side of the inlet, which connects Nixon Channel to the ocean, will migrate towards and directly connect with the main channel (Figure 11-43 and Sub-Appendix B). These changes are generally similar to what has occurred in the past (see Figure 11-44).

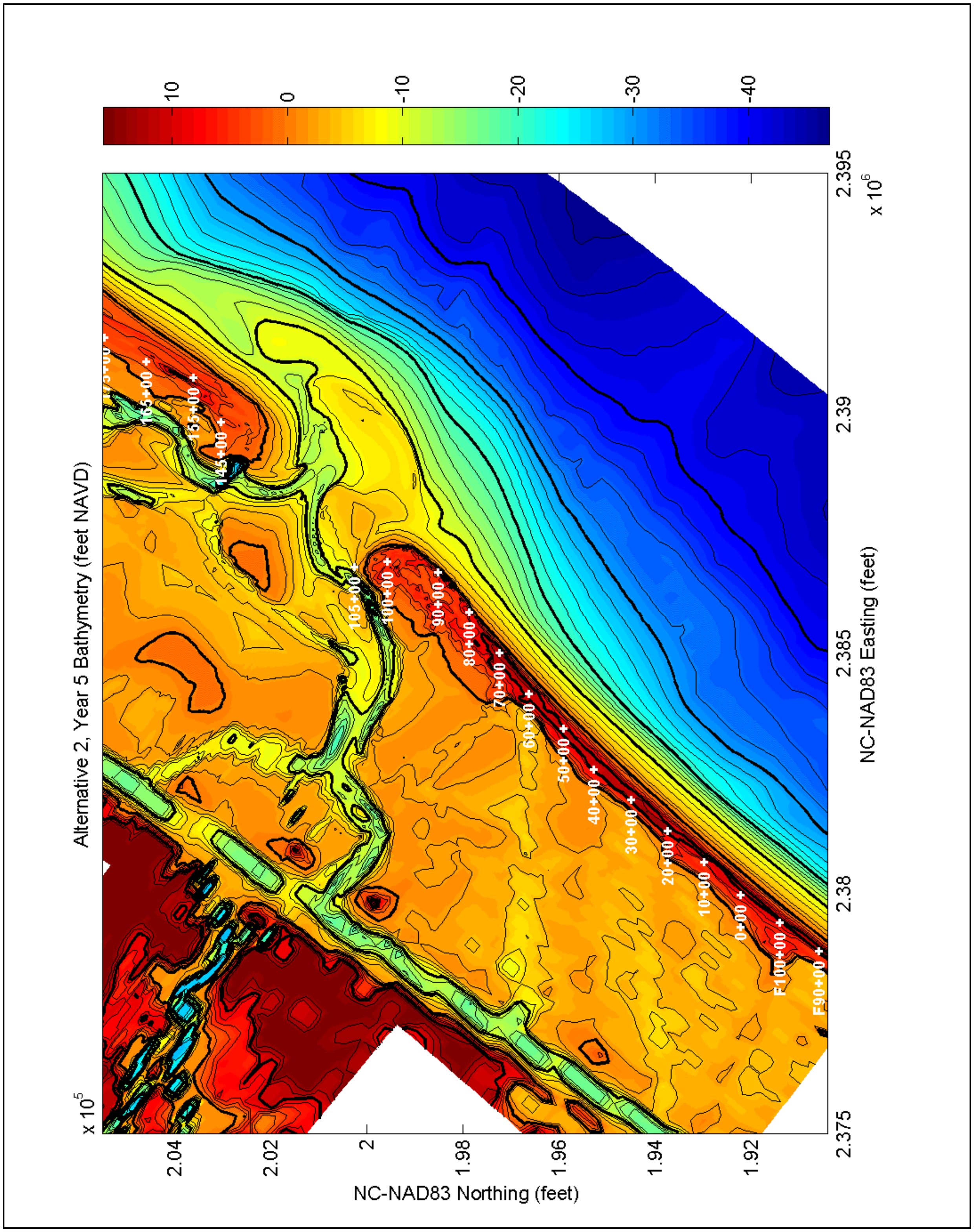


**FIGURE 11-43: Bathymetry in Rich Inlet at Year 5 Given Alternative 2.**

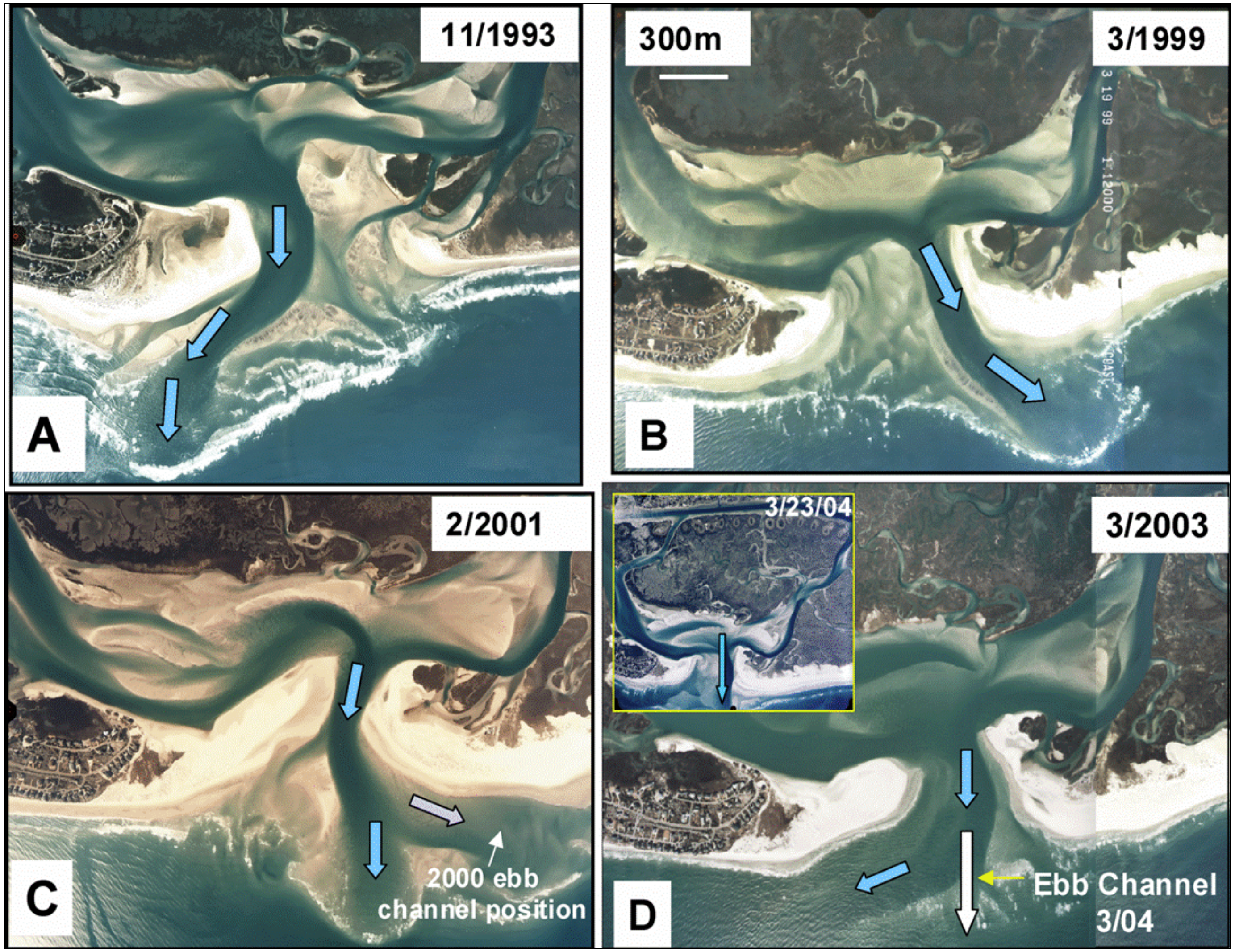


**FIGURE 11-44: Aerial photographs of Rich Inlet (11/1993-3/2004). Photographs A-D depict shoreline changes related to deflection of ebb channel (blue arrows) and subsequent repositioning and reorientation through ebb delta breaching in late 2002 (C) and late 2003 after channel deflected toward Figure Eight Island (D). Insert in D shows ebb channel as of March 2004 (Figure and caption from Cleary & Jackson, 2004).**

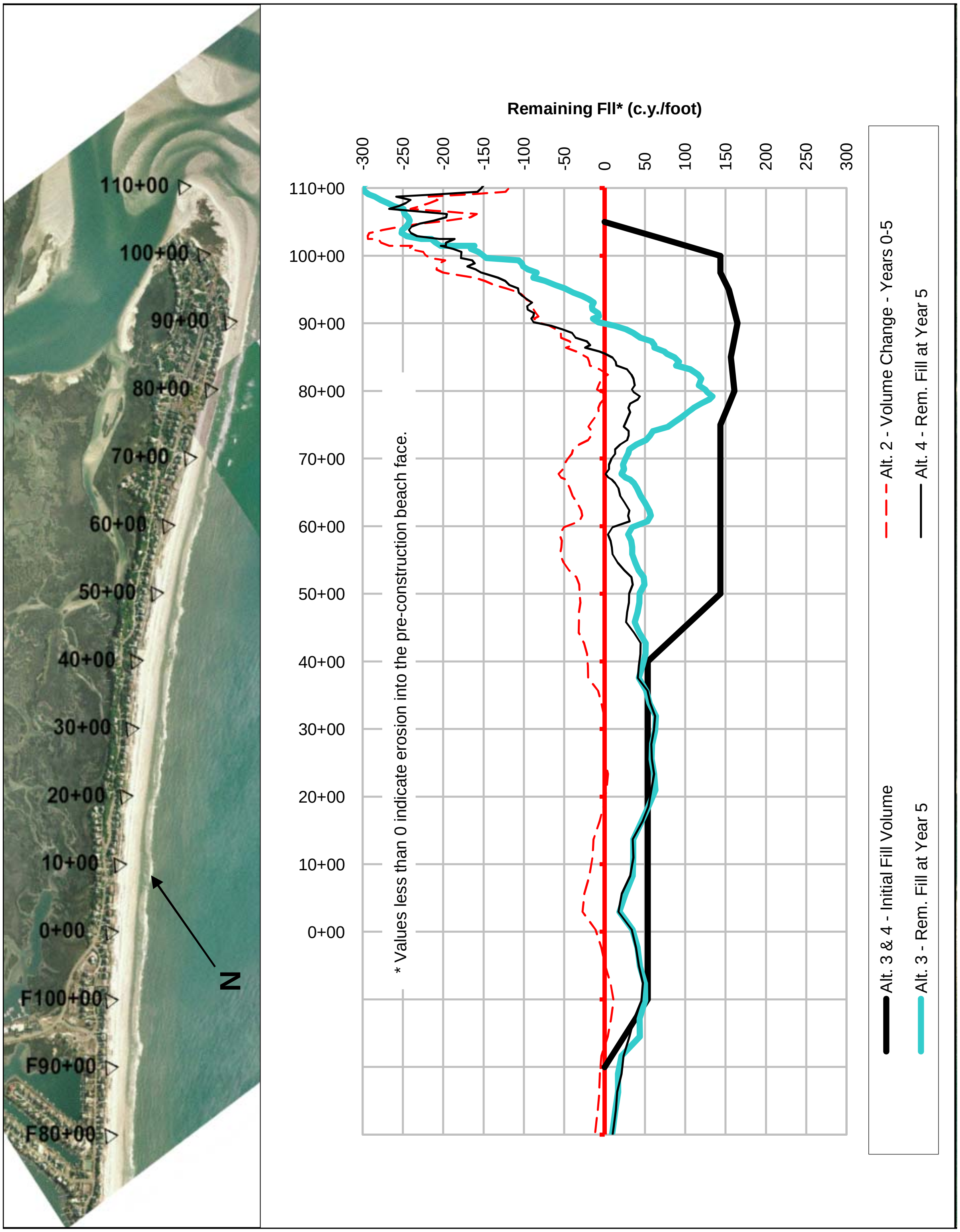


**FIGURE 11-45: 5 Year Volume Changes on Figure Eight Island Given Alternatives 2, 3, & 4.**

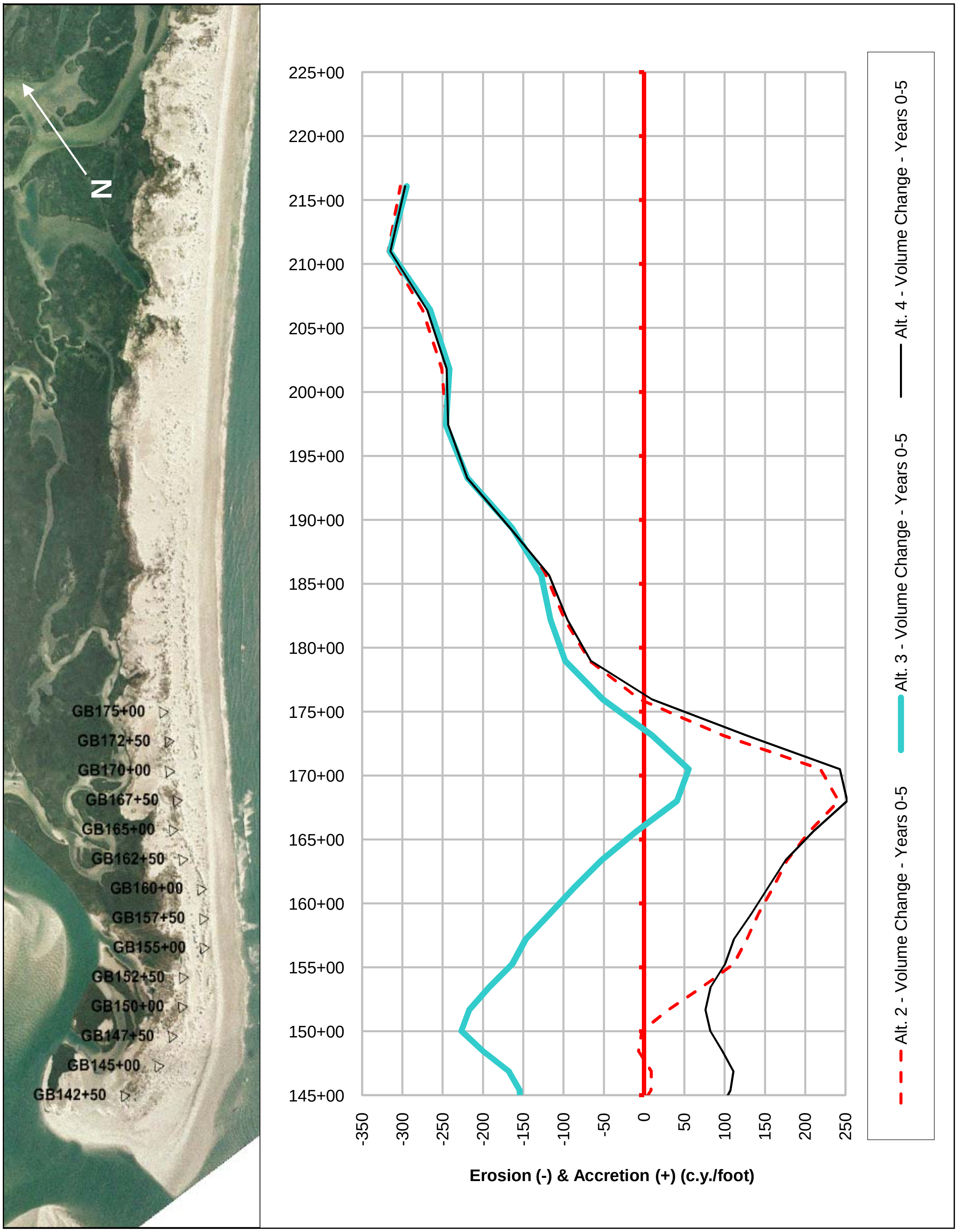


**FIGURE 11-46: 5 Year Volume Changes on Hutaff Island Given Alternatives 2, 3, & 4.**

**TABLE 11-7**

**DELFT3D PROJECTED VOLUME CHANGES**
**FIGURE EIGHT ISLAND, NC**

| Profile Lines | | | 5-year Volume Change, Alt. 2 (c.y.) | Alternative 3 & 4 Remaining Fill (c.y.) | | | Alternative 5a Remaining Fill (c.y.) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Year 0 | Alt. 3 Year 5 | Alt.4 Year 5 | Year 0 | 700' Groin Year 5 | 1200' Groin Year 5 |
| F90+00 | to | F100+00 | 3,543 | 26,800 | 37,381 | 32,220 | 16,100 | 27,466 | 25,412 |
| F100+00 | to | 0+00 | 1,240 | 53,600 | 44,439 | 42,341 | 32,200 | 39,934 | 37,173 |
| 0+00 | to | 10+00 | -21,324 | 53,500 | 28,149 | 25,666 | 32,100 | 22,214 | 17,954 |
| 10+00 | to | 20+00 | -8,950 | 53,500 | 43,328 | 43,217 | 32,100 | 42,535 | 38,107 |
| 20+00 | to | 30+00 | 1,131 | 53,500 | 60,484 | 59,266 | 32,100 | 61,888 | 53,979 |
| 30+00 | to | 40+00 | -9,265 | 53,500 | 53,392 | 52,561 | 32,100 | 56,762 | 48,939 |
| 40+00 | to | 50+00 | -28,497 | 98,600 | 44,502 | 35,242 | 59,100 | 48,901 | 38,400 |
| 50+00 | to | 60+00 | -46,071 | 143,600 | 38,984 | 18,293 | 86,100 | 43,920 | 30,482 |
| 60+00 | to | 70+00 | -41,354 | 143,600 | 40,069 | 17,295 | 86,100 | 54,027 | 37,854 |
| 70+00 | to | 72+50 | -9,332 | 35,900 | 8,286 | 3,738 | 21,500 | 13,651 | 9,622 |
| 72+50 | to | 75+00 | -4,553 | 35,900 | 15,399 | 6,975 | 21,500 | 17,587 | 12,741 |
| 75+00 | to | 77+50 | -2,874 | 35,900 | 24,171 | 7,209 | 24,500 | 17,602 | 12,107 |
| 77+50 | to | 80+00 | -709 | 39,200 | 31,266 | 9,196 | 33,600 | 19,389 | 13,012 |
| 80+00 | to | 82+50 | -1,182 | 40,000 | 29,836 | 8,892 | 40,300 | 16,824 | 9,932 |
| 82+50 | to | 85+00 | -3,209 | 39,400 | 24,333 | 4,886 | 45,500 | 12,761 | 6,381 |
| 85+00 | to | 87+50 | -9,397 | 39,600 | 17,035 | -3,002 | 51,600 | 7,529 | 3,100 |
| 87+50 | to | 90+00 | -14,754 | 40,700 | 7,526 | -12,109 | 58,600 | 120 | 397 |
| 90+00 | to | 92+50 | -21,275 | 40,500 | -2,690 | -22,599 | 64,200 | -2,689 | 3,837 |
| 92+50 | to | 95+00 | -24,657 | 39,200 | -6,406 | -24,740 | 68,800 | 1,764 | 15,422 |
| 95+00 | to | 97+50 | -38,060 | 35,900 | -17,992 | -31,506 | 54,100 | 7,158 | 33,549 |
| 97+50 | to | 100+00 | -51,783 | 35,900 | -27,226 | -41,389 | 20,800 | 25,188 | 62,518 |
| 100+00 | to | 102+50 | -62,563 | 26,900 | -45,047 | -47,113 | 0 | -14,701 | -10,096 |
| 102+50 | to | 105+00 | -67,123 | 9,000 | -61,460 | -58,466 | 0 | -67,244 | -60,990 |
| | | | | | | | | | |
| F90+00 | to | 30+00 | -24,360 | 240,900 | 213,781 | 202,710 | 144,600 | 194,037 | 172,625 |
| 30+00 | to | 60+00 | -83,833 | 295,700 | 136,878 | 106,096 | 177,300 | 149,583 | 117,821 |
| 60+00 | to | 77+50 | -58,113 | 251,300 | 87,925 | 35,217 | 153,600 | 102,867 | 72,324 |
| 77+50 | to | 95+00 | -75,183 | 278,600 | 100,900 | -39,476 | 362,600 | 55,698 | 52,081 |
| 95+00 | to | 100+00 | -89,843 | 71,800 | -45,218 | -72,895 | 74,900 | 32,346 | 96,067 |
| 100+00 | to | 105+00 | -129,686 | 35,900 | -106,507 | -105,579 | 0 | -81,945 | -71,086 |
| | | | | | | | | | |
| F90+00 | to | F100+00 | -461,018 | 1,174,200 | 387,759 | 126,073 | 913,000 | 534,531 | 510,918 |

**TABLE 11-8**

**DELFT3D PROJECTED VOLUME CHANGES**
**HUTAFF ISLAND, NC**

| Profile Lines | | | 5 Year Volume Change (c.y.) | | | | |
|---|---|---|---|---|---|---|---|
| | | | Alt. 2 | Alt .3 | Alt .4 | Alt. 5a (700' Groin) | Alt. 5a (1,200' Groin) |
| 145+00 | to | 147+50 | 1,933 | -40,837 | 27,084 | -21,584 | -23,694 |
| 147+50 | to | 150+00 | -921 | -51,095 | 23,600 | -11,577 | -10,914 |
| 150+00 | to | 152+50 | 5,576 | -54,565 | 19,664 | 3,203 | 5,085 |
| 152+50 | to | 155+00 | 19,478 | -46,816 | 21,654 | 19,605 | 20,723 |
| 155+00 | to | 157+50 | 29,834 | -38,787 | 26,518 | 28,126 | 28,550 |
| 157+50 | to | 160+00 | 34,732 | -30,953 | 32,062 | 29,972 | 29,136 |
| 160+00 | to | 162+50 | 39,989 | -21,600 | 38,480 | 25,936 | 23,086 |
| 162+50 | to | 165+00 | 45,707 | -11,281 | 45,548 | 18,909 | 15,412 |
| 165+00 | to | 167+50 | 53,761 | 926 | 55,314 | 18,665 | 16,417 |
| 167+50 | to | 170+00 | 58,378 | 11,120 | 62,101 | 22,703 | 21,080 |
| 170+00 | to | 172+50 | 45,582 | 10,327 | 51,942 | 17,295 | 16,014 |
| 172+50 | to | 175+00 | 18,988 | -931 | 25,406 | 1,894 | 1,359 |
| 145+00 | to | 175+00 | 353,037 | -274,492 | 429,373 | 153,147 | 142,254 |

Within Nixon Channel, the depth near the north end of Beach Road will increase from -16 feet NAVD to -23 feet NAVD.

Volume changes along the beach appear in Table 11-7, Table 11-8, Figure 11-45, and Figure 11-46. Between Comber Road (profiles 80+00 to 105+00), severe erosion will occur, with 5-year losses of up to 293 c.y./foot. The total loss over this area over the next 5 years will be 294,000 cubic yards. South of Comber Road, the beach will be stable or mildly erosional, with a 5 year loss of 167,000 cubic yards between Comber Road and Beach Bay Lane (profile F90+00). The south end of Hutaff Island (profiles 145+00 to 175+00) will be accretional, gaining 353,000 cubic yards. North of profile 175+00, erosion will occur. On both sides of Rich Inlet, the projected erosional patterns along the beach are consistent with the general erosion patterns over the past 14 years.

### 11.4.3 Alternative 3 – Rich Inlet Management and Beach Fill

If Alternative 3 is constructed, the main channel of Rich Inlet will shift its orientation over the project duration. At Year 2, it will assume a north / south orientation, while at Year 5, it will assume a west-northwest / east-southeast orientation (Figures 11-47 and 11-48). These changes in orientation are consistent with the historical behavior of the inlet (see Figure 11-44). Between Years 0 and 2, the perimeter of the ebb shoal will migrate towards the south. This motion will continue between Years 2 and 5. However, as the channel switches orientation and position, it will leave a "hole" in the ebb shoal.

Results beyond Year 5 are not shown since the maintenance plan would involve the re-dredging of the channel at Year 5. If no re-dredging took place at Year 5, the hole in the ebb shoal would probably fill in as the material on the seaward side of it migrates towards the beach. If maintenance dredging were conducted at Year 5, the amount of material that would have to be removed from the dredge cuts to restore them to the original design conditions could range from 1,165,000 to 1,297,000 cubic yards (Table 11-9).

**TABLE 11-9**

**DELFT3D DREDGE MAINTENANCE VOLUMES**
**EIS ALT. 3 WITH PREFERRED DREDGING OPTION**

| Year | Dredge Maintenance Volume (c.y.) Design Depth | | | |
|---|---|---|---|---|
| | Entrance Channel | Nixon Channel | Green Channel | TOTAL |
| 1 | 257,000 | 117,000 | 89,000 | 463,000 |
| 2 | 460,000 | 179,000 | 157,000 | 796,000 |
| 3 | 591,000 | 204,000 | 143,000 | 938,000 |
| 4 | 537,000 | 235,000 | 135,000 | 907,000 |
| 5 | 716,000 | 307,000 | 142,000 | 1,165,000 |

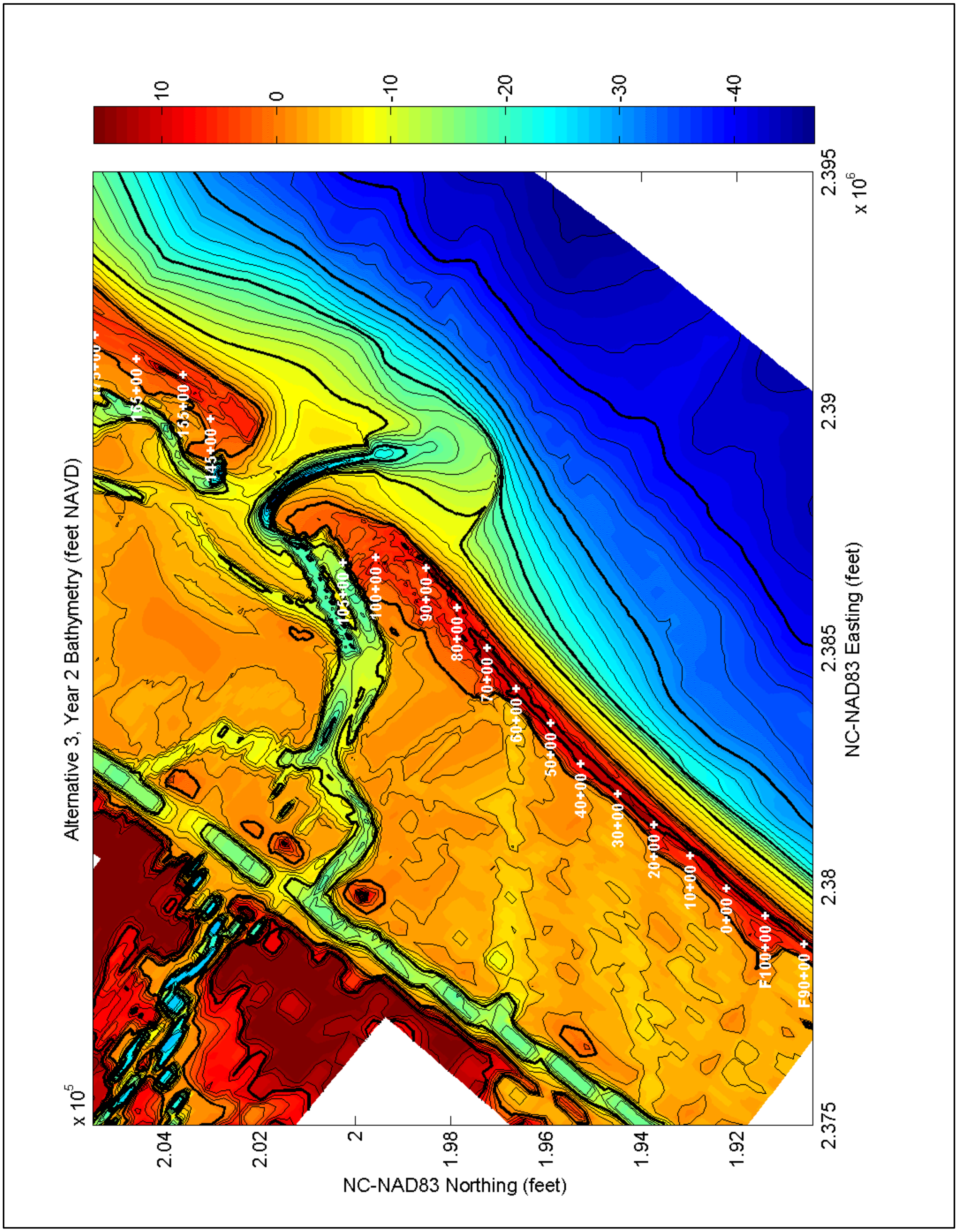


**FIGURE 11-47: Bathymetry in Rich Inlet at Year 2 Given Alternative 3.**

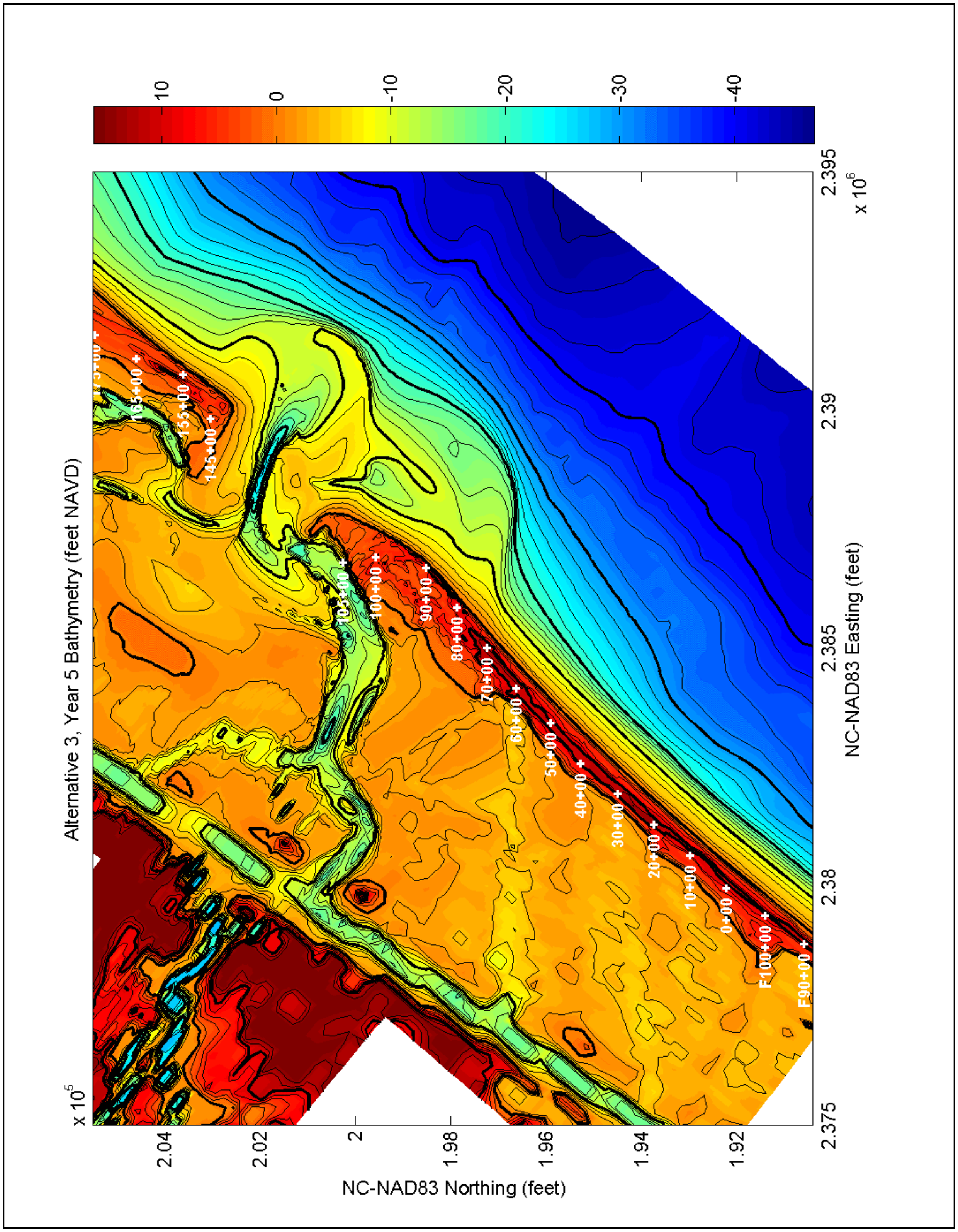


**FIGURE 11-48: Bathymetry in Rich Inlet at Year 5 Given Alternative 3.**

**TABLE 11-9 (continued)**

**DELFT3D DREDGE MAINTENANCE VOLUMES**
**EIS ALT. 3 WITH PREFERRED DREDGING OPTION**

| Year | Dredge Maintenance Volume (c.y.) Design Depth + 1 foot overdepth | | | |
|---|---|---|---|---|
| | Entrance Channel | Nixon Channel | Green Channel | TOTAL |
| 1 | 306,000 | 149,000 | 102,000 | 557,000 |
| 2 | 520,000 | 210,000 | 173,000 | 903,000 |
| 3 | 658,000 | 236,000 | 157,000 | 1,051,000 |
| 4 | 609,000 | 269,000 | 148,000 | 1,026,000 |
| 5 | 792,000 | 349,000 | 156,000 | 1,297,000 |

Volume changes along the beach appear in Figures 11-45 and 11-46 and Tables 11-7 and 11-8. South of Inlet Hook Road (profile 90+00), there is no erosion into the pre-construction beach face over the 5 year maintenance interval. The amount of fill remaining on this segment (profiles F90+00 to 90+00) at Year 5 is 549,000 cubic yards, or 56 percent of the segment's design volume (986,800 c.y.). Along Inlet Hook Road (profiles 90+00 to 95+00), erosion into the beach face could occur, although it will not begin until Year 4. The amount of erosion into the pre-construction beach face through Year 5 will be 9,000 c.y. along Inlet Hook Road, with a maximum value of 50 c.y./foot at profile 95+00. North of profile 95+00, the distances between the building line and the shoreline are relatively large. Thus, the damage risks posed by erosion into the pre-construction profile are not as high. Overall, by moving the channel and inducing movement of the ebb shoal, Alternative 3 would reduce losses from a beach fill along the north end of Figure Eight Island compared to the performance of fills under existing conditions. Based on the model results, the 5-year nourishment requirement for the beach fill along the ocean shoreline under Alternative 5A would be approximately 786,500 cubic yards. Maintenance of the Nixon Channel beach fill would require approximately 30,000 cubic yards every five years resulting in a total 5-year nourishment requirement of 816,500 cubic yards.

The predicted shoaling rate in the dredged channels provided in Table 11-9 indicates most of this periodic beach nourishment could be obtained from maintenance of just the entrance channel. In this regard, once the new bar channel is established and the new channel connectors constructed into both Nixon and Green Channels, future maintenance of the connecting channels will probably not be required nor would maintenance of these two channel connectors be desirable given the repetitive disturbance this dredging activity would have on the estuarine environment. Since the main focus of Alternative 3 is to provide a new entrance channel that would create a favorable shoreline response on the north end of Figure Eight Island, future maintenance of the channels under Alternative 5A would be limited to maintaining the preferred position and alignment of the entrance channel and distributing this material along both the ocean and Nixon Channel beach fill areas. Future maintenance of the channel connectors into Nixon and Green Channels would be deferred and would only occur following consultation with both the Federal and State permitting and resources protection agencies.

The upper limit of predicted shoaling in the entrance channel is 792,000 cubic yards every 5 years (Table 11-9) which is slightly less than the predicted 5-year nourishment needs for both beach fill areas. However, given the relatively small difference in the predicted nourishment requirements and channel shoaling rate, the cost of maintaining Alternative 3 will be based on removing 792,000 cubic yards every 5 years from the entrance channel and using that material to maintain the two beach fills. Any shortfalls in beach nourishment requirements would be minor and would not have a significant impact on the overall protective value afforded by the fills.

If Alternative 3 is constructed, the south end of Hutaff Island will become erosional. This occurs due to the migration of the ebb shoal towards the south. The amount of erosion between profiles 145+00 and 175+00 will be 275,000 cubic yards, which represents an annual erosion rate of 54,900 cubic yards/year compared to the existing rate of accretion of 70,600 cubic yards/year. It should be noted that this overall volume loss from Hutaff Island does not include the addition of 513,700 cubic yards that would be used to construct the closure dike off the extreme south end of the island.

### 11.4.4 Alternative 4 – Beach Fill without Management of Rich Inlet

The Alternative 4 beach fill performed essentially the same as the Alternative 3 fill between F90 and 30, retaining almost 84% of the initial fill volume over the 5-year simulation period. Over the first three years of the simulation, the Alternative 4 beach fill performance between stations 30+00 and 60+00 matched that of Alternative 3; however, beginning in year 4, losses from the Alternative 4 fill began to exceed the losses of the Alternative 3 fill. Between stations 60+00 and 80+00, the Alternative 3 and 4 fills performed the same over the first two years but losses from the Alternative 4 fill began to increase starting in year 3 of the simulation. The difference of the performance of the fills between Alternatives 3 and 4 in the area from stations 30+00 to 80+00 can be attributed to the changes in the configuration of the ebb tide delta induced by the repositioned channel associated with Alternative 3. The increased losses from the southern portions of the fill over time are also consistent with the loss of feeder material associated with the erosion in the northern beach segments.

For the area closest to Rich Inlet (80+00 to 100+00), the Alternative 4 fill experienced rapid losses with the entire fill disappearing sometime between year 2 and 3 of the simulation. By the end of year 5 of the simulation, this segment had lost 122,000 cubic yards over and above the volume of material included in the initial fill. The loss of the fill from this segment reduced the sediment transport to the south resulting in the higher rates of loss during the latter years of the simulation in the area between 30+00 and 80+00 as mentioned above. The performance of the fill between 80+00 and 100+00 mimics what has been observed following 6 pervious beach nourishment attempts on the north end of Figure Eight Island, some of which are documented by Dr. Cleary in Sub-Appendix A of Appendix C. While the 6 previous beach fills were relatively small (less than 300,000 cy) compared to the beach fill volume simulated for Alternative 4, all of the fill material included in these 6 beach fills was lost from the area fronting the sandbag revetments within a matter of months following placement.

As mentioned above, the performance of the beach fill under Alternative 4 was used to re-design the initial beach fill by reducing the initial fill volume in the area between stations F90+00 and 80+00 and increasing the volume between stations 80+00 and 100+00. Also, since the model indicated high rates of loss for the area between 80+00 and 100+00 during the first three years of the simulation, the design of the fill for Alternative 4 was based on a three-year nourishment cycle.

Over 50% of the fill volume remained in the area between F90+00 and 80+00 at the end of 3 years indicating the fill volume used in the model simulation was over designed and could be reduced. Likewise, the model indicated erosion into the upland area between stations 80+00 and 100+00 by the end of year 3 indicating more material would be needed in this area. The re-designed fill distribution for Alternative 4 is provided in Table 9-5 with the total fill volume along the ocean shoreline equal to 864,300 cubic yards. This is about 309,900 cubic yards less than the fill for Alternative 3 which again was based on the volume of material to be removed to reconfigure Rich Inlet. The Nixon Channel shoreline would also receive 65,000 cubic yards resulting in a total fill volume under Alternative 4 of 929,300 cubic yards.

At the end of 3 years, the amount of initial fill remaining ranged from 17.1% for the area between stations 30+00 and 80+00 to 13.6% for the area from stations 80+00 to 100+00.

### 11.4.5 Alternative 5A - Terminal Groin with Beach Fill from Nixon Channel

To evaluate groin and beach fill performance, several variations of Alternative 5A were simulated:

- Alt. 5A-1, terminal Groin (700 feet) with Beach Fill from Nixon Channel
- Alt. 5A-2, terminal Groin (1,200 feet) with Beach Fill from Nixon Channel
- Alt. 5A-3a, terminal Groin (700 feet) without Oceanfront Beach Fill
- Alt. 5A-3b, terminal Groin (1,200 feet) without Oceanfront Beach Fill
- Alt. 5A-2 with 10° oblique terminal groin (1,200 feet)
- Alt. 5A-2 with 20° oblique terminal groin (1,200 feet)
- Alt. 5A-2 with 30° oblique terminal groin (1,200 feet)

The length of each groin above is the length relative to the April 2007 shoreline position, and does not include the landward segment of the structure. The “oblique” terminal groins are laid out at an angle to the groin alignment in Figure 9-15. Model results given all 7 variations appear in Sub-Appendix B. Model results given the first 4 variations above appear in Figures 11-49 to 11-52 and Tables 11-7 and 11-8.

A terminal groin without beach fill would be able to lower the erosion rates on the northern end of Figure Eight Island (see Figure 11-49). If the groin extended 700 feet seaward of the present shoreline, it would reduce the erosion rates between Inlet Hook Road (profile 90+00) and the structure. It would also reduce erosion rates between Bridge Road and Comber Road (profiles F100+00 to 80+00).

If the groin extended 1,200 feet seaward of the present shoreline, accretion would occur between profile 95+00 and the structure. However, this short segment is located north of the sandbagged homes on Inlet Hook Road and is not critically eroded. Between the north end of Surf Court and the south end of Inlet Hook Road (profiles 75+00 to 90+00), erosion rates predicted by the model actually increased. South of Surf Court (profile 70+00), changes to erosion rates were minimal or negligible.

Figure 11-49 shows that the shorter groin is the better structure. Extending the structure seaward increases the transfer of material from the sandbagged beachfront to the groin fillet. Given its larger cost and impact, the longer groin is not justified.

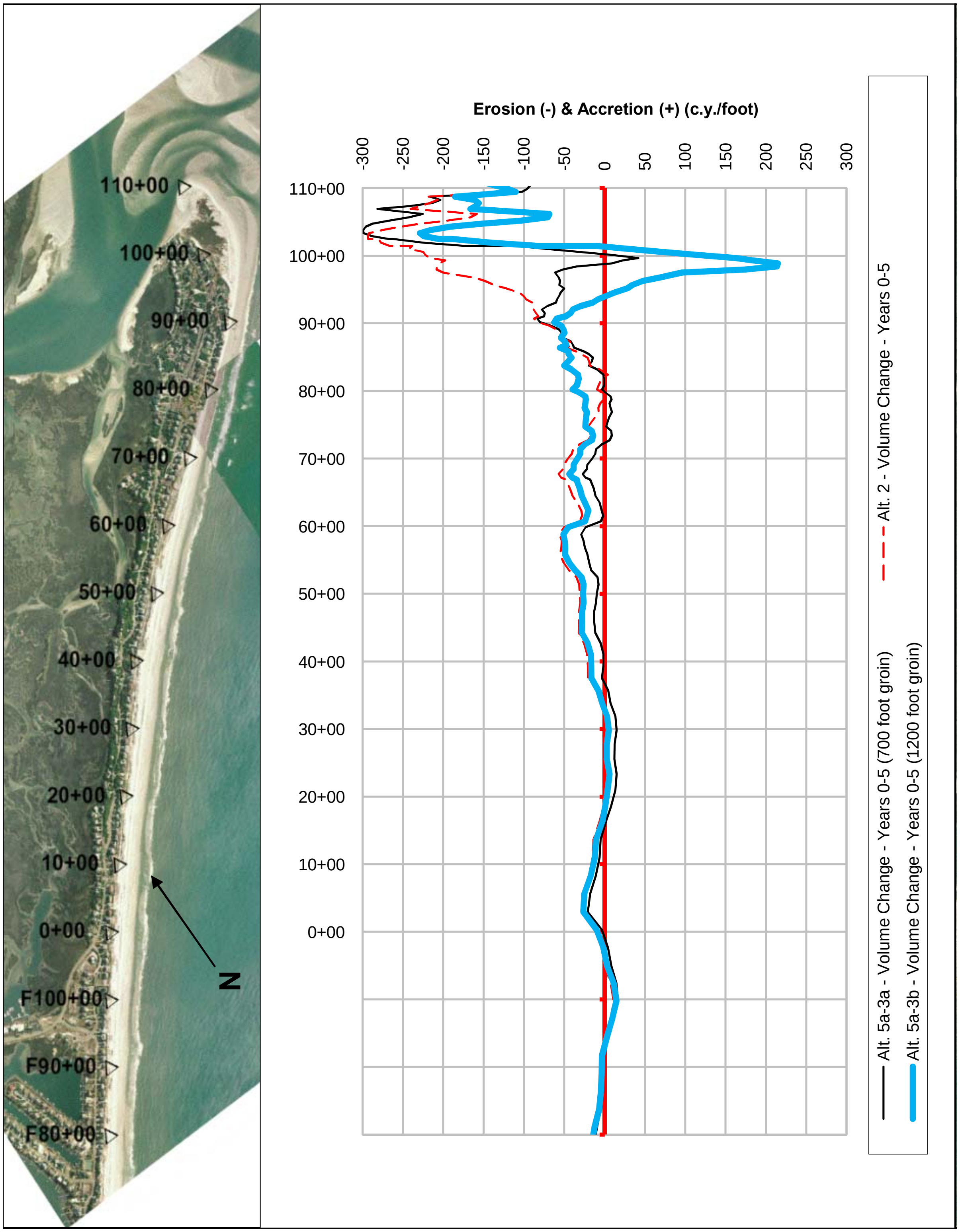


**FIGURE 11-49: 5 Year Volume Changes on Figure Eight Island Given Alternative 5a, 700 or 1200 foot Terminal Groin without Beach Fill.**

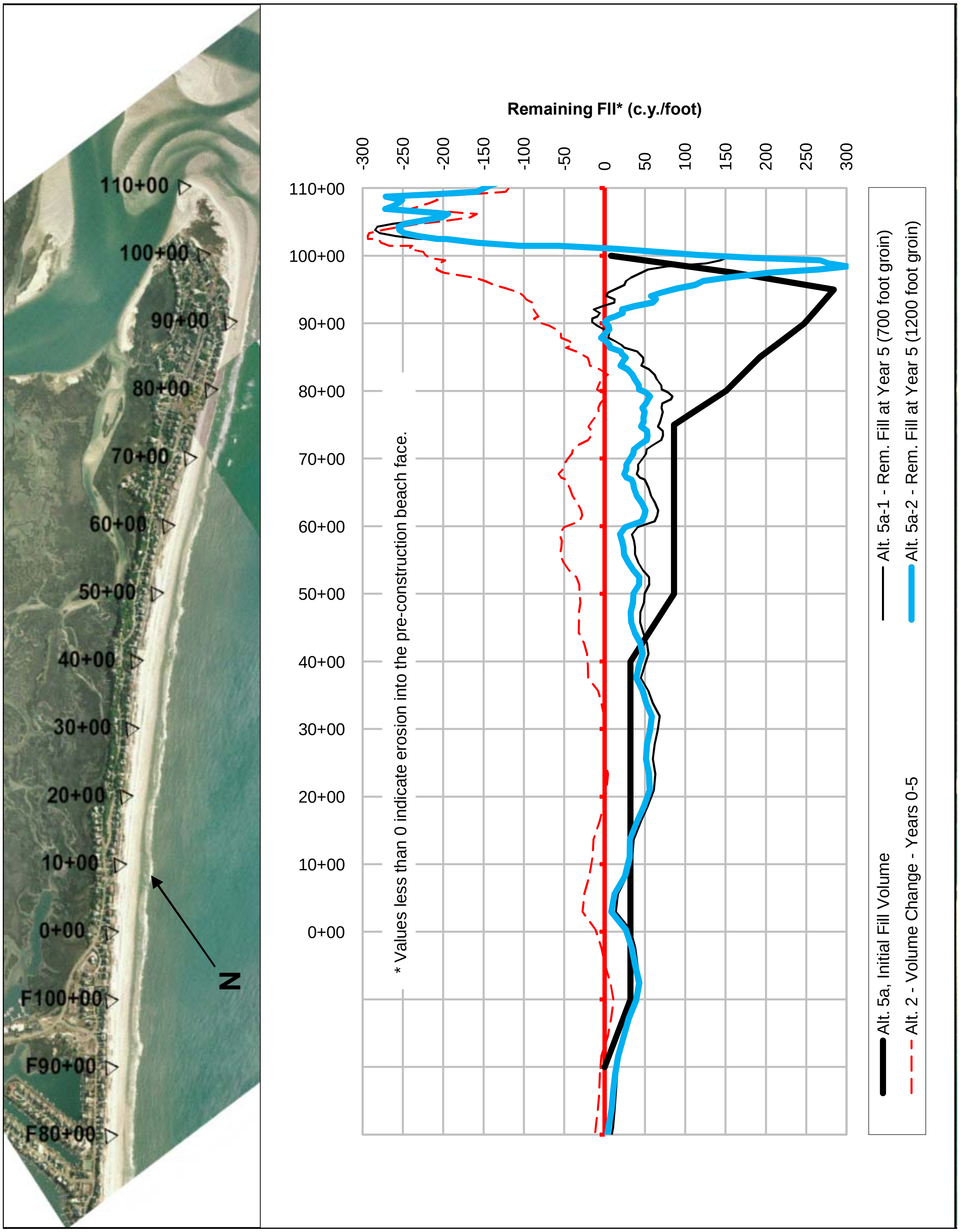


**FIGURE 11-50: 5 Year Volume Changes on Figure Eight Island Given Alternative 5a, 700 or 1200 foot Terminal Groin with Beach Fill.**

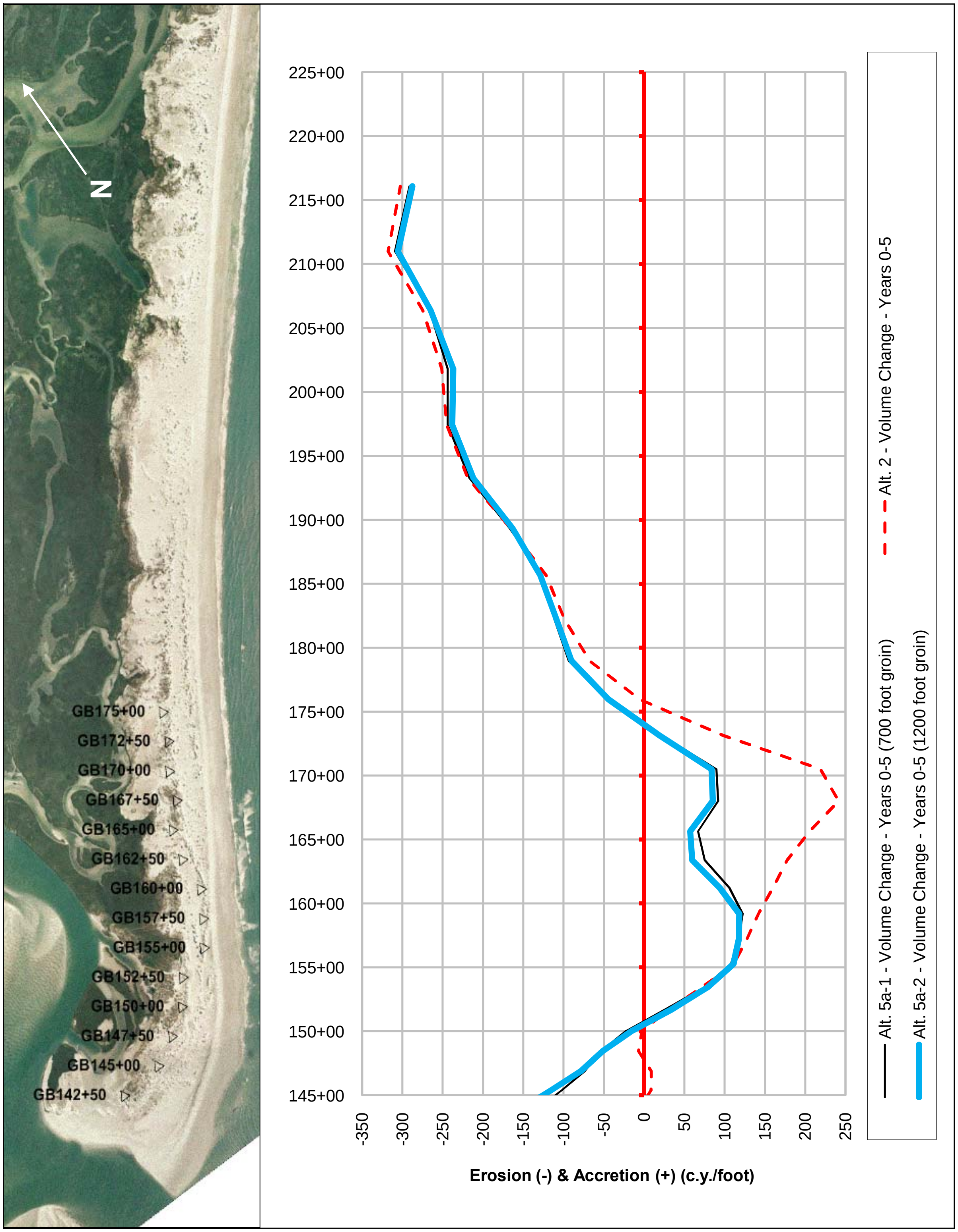


**FIGURE 11-51: 5 Year Volume Changes on Hutaff Island Given Alternative 5a, 700 or 1200 foot Terminal Groin with Beach Fill.**

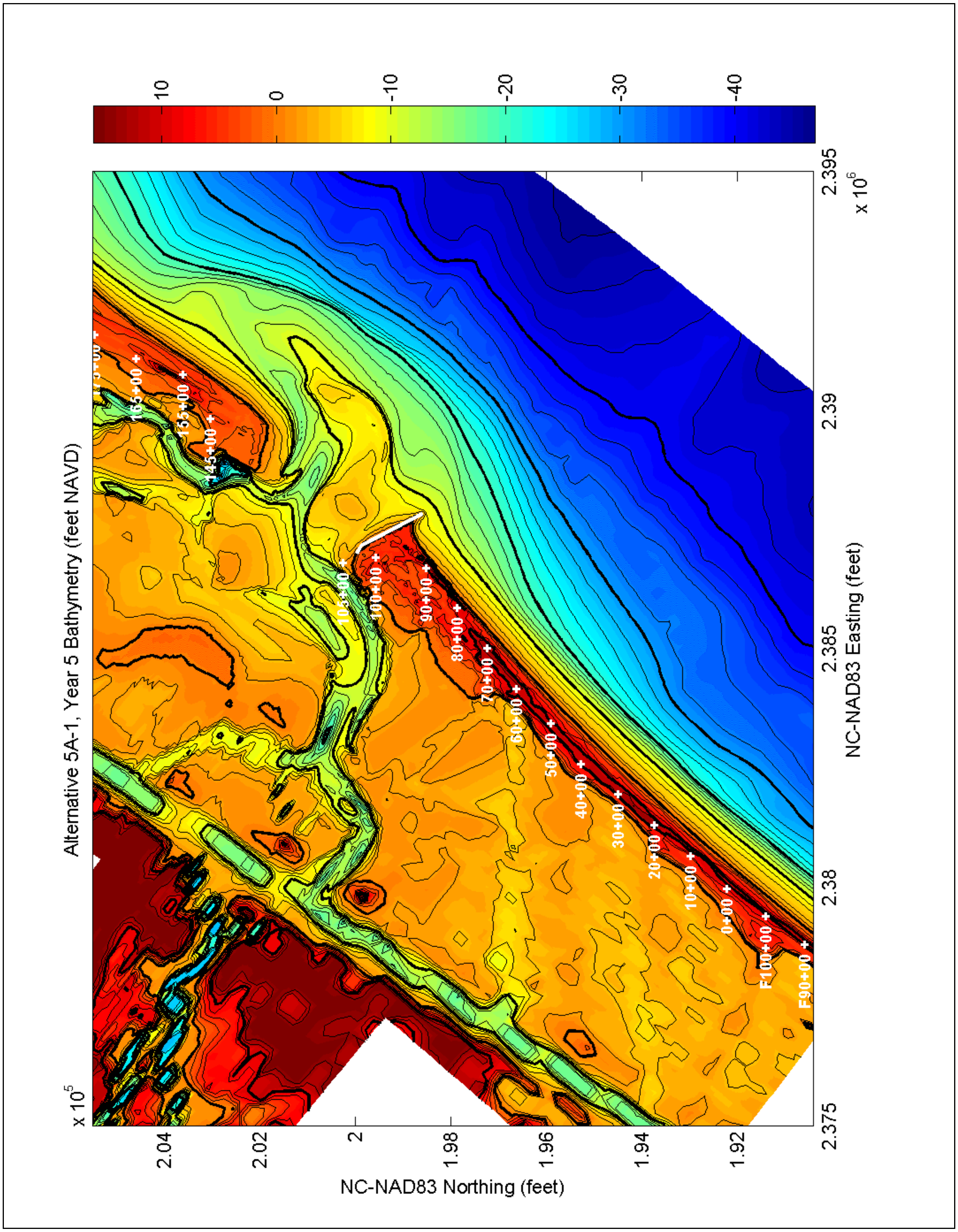


**FIGURE 11-52: Bathymetry in Rich Inlet at Year 5 Given Alternative 5A (700 Foot Groin with Beach Fill).**

Figure 11-49 also shows that without beach fill, a groin can provide only a partial solution to the critical erosion problem north of Surf Court. This is due to the fact that the area subject to northerly sediment transport is relatively short (see Figures 8-4, 8-5, and 11-40). Material lost from the critically eroded properties spreads to both the north and the south, limiting fillet growth. As shown in Figure 11-49, extending the groin actually increases erosion rates in some sections. Thus, the only way for terminal groin to be effective is to pre-fill the structure and nourish the beaches to the south.

If a 700 foot terminal groin were constructed with beach fill, erosion into the pre-construction beach face would be prevented along most of the fill area over 5 years. A small amount of erosion into the present shoreline could occur near the south end of Inlet Hook Road (profile 90+00). The overall amount of fill remaining at Year 5 would be 534,000 cubic yards, or 59% of the original fill volume. If the groin length were increased, erosion into the pre-construction beach face would be minimal. However, it would lessen performance of the fill south of Inlet Hook Road, particularly along Comber Road (profiles 77+50 to 87+50). For the longer groin, the overall amount of fill remaining at Year 5 would be 511,000 cubic yards, or 56% of the original fill volume. Given these findings, adjusting the beach fill layout during the permitting or bidding process is the more cost-effective means of improving beach fill performance. The amount of material in the dredge cut for renourishment at Year 5 will range from 472,000 to 589,000 cubic yards (Table 11-10).

**TABLE 11-10**

**DELFT3D DREDGE MAINTENANCE VOLUMES**
**EIS ALT. 5A – 700 FOOT GROIN WITH BEACH FILL**

| Year | Dredge Maintenance Volume (c.y.) Design Depth -11' MLW (-13.43' NAVD) Cut | Dredge Maintenance Volume (c.y.) Design Depth -9' MLW (-11.43' NAVD) Cut | Total |
|---|---|---|---|
| 1 | 303,000 | 20,000 | 323,000 |
| 2 | 420,000 | 56,000 | 476,000 |
| 3 | 438,000 | 97,000 | 535,000 |
| 4 | 474,000 | 117,000 | 591,000 |
| 5 | 338,000 | 134,000 | 472,000 |
| **Year** | **Dredge Maintenance Volume (c.y.) Design Depth + 1' Overdepth** -11' MLW (-13.43' NAVD) Cut | -9' MLW (-11.43' NAVD) Cut | **Total** |
| 1 | 359,000 | 61,000 | 420,000 |
| 2 | 486,000 | 94,000 | 580,000 |
| 3 | 506,000 | 139,000 | 645,000 |
| 4 | 541,000 | 163,000 | 704,000 |
| 5 | 407,000 | 182,000 | 589,000 |

For Alternative 5A, changes in the inlet (Figure 11-52) will be similar to those given for the without-project scenario (Alternative 2, Figure 11-43), except for the following:

- The deep section of main channel will be broader, with maximum depths of -18 feet NAVD instead of -14 feet NAVD. This will occur due to the connecting cut between the previous dredged area and the main channel of the inlet (see Figures 9-18 and 11-52).

- The deep section of Nixon Channel will be broader but shallower. Opposite the north end of Beach Road, a "double channel" may form in Nixon Channel. The maximum depth near the north end of Beach Road will be -17 feet NAVD instead of -23 feet NAVD. Both changes will occur due to the presence of the dredge cuts.

The Delft3D model also predicts that the subaerial land north of the groin will become submerged. However, this process also occurs under the without-project scenario, as shown in Figure 11-53. Since the proposed groin location coincides with the 1970 inlet shoreline, the changes shown in Figure 11-53 are within the natural variability of the inlet.

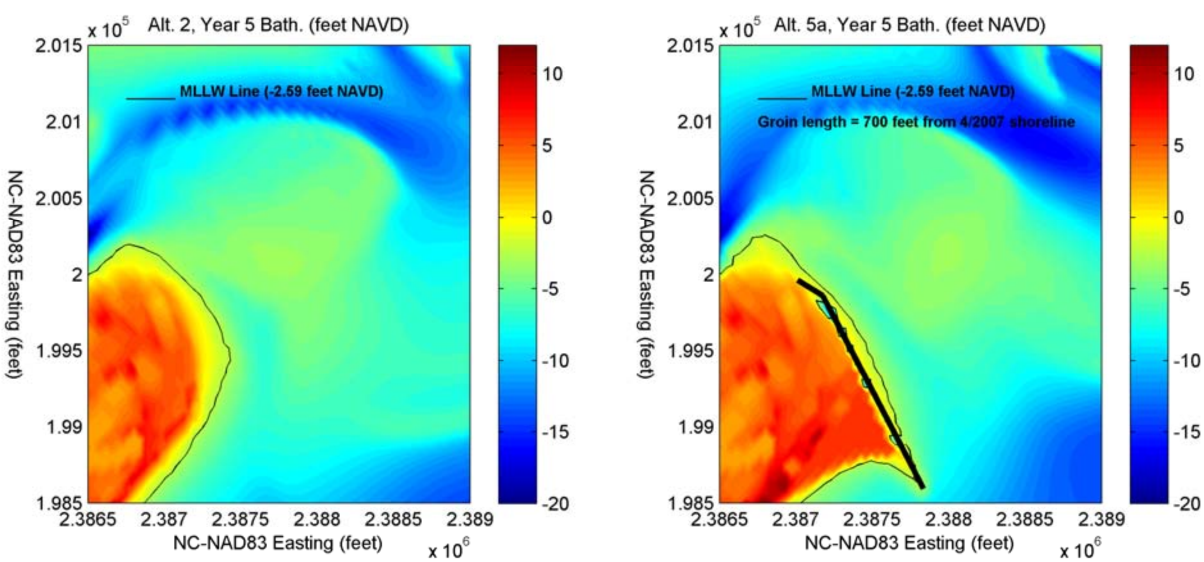


**FIGURE 11-53: Year 5 Topography and Bathymetry near Proposed Groin Location.**

### 11.4.6 Alternative 5B – Terminal Groin with Beach Fill from Other Sources

Alternative 5B was not directly modeled in Delft3D; rather, the changes associated with 5B were extrapolated from the results of the other terminal groin model simulations as explained below.

Changes in the inlet's morphology for Alternative 5B were assumed to be the same as Alternative 5A even though 5B would not include a new channel connector between Rich Inlet and Nixon Channel. While the presence of the channel connector would divert more flow into Nixon Channel compared to what would occur under Alternative 5B, this difference was not deemed to be significant in terms of the overall changes that would occur to Rich Inlet. Under 5B, the sand spit on the north end of Figure Eight Island would be expected to disappear in much the same manner as was predicted for Alternative 2, the without project condition, and Alternative 5A.

The model results for Alternative 5A-3a, which included the 700-foot terminal groin without beach fill, were used to represent the worst cast condition for Alternative 5B with regard to potential impacts along Figure Eight Island, Hutaff Island, and within the Rich Inlet complex. Under this condition, the estimated volume change on Hutaff Island was accretion at a rate of 29,400 cubic yards/year or essentially the same as for Alternative 5A which produced an accretion rate of 30,600 cubic yards/year. These predicted accretion rates on Hutaff Island are still less than the predicted rate obtained from the model for Alternative 2.

The projected performance of the beach fill for Alternative 5B was based on the volume of initial beach fill retained within the area between stations 60+00 and 100+00 indicated by the results of the Delft3D simulation for Alternative 5A. In this regard, 65.3% of the initial beach fill volume should still be in place between stations 60+00 and 80+00 at the end of 5-years with 17.0% remaining in the area between stations 80+00 and 100+00.

### 11.5 Tidal Prisms & Flow Distributions

Average tidal prisms and the standard deviation of the tidal prisms over the 5-year simulation period determined from the results of the Delft3D simulations for Alternatives 2, 3, 4 and 5A appear in Table 11-11 and Figures 11-54 to 11-56. Tidal prisms are provided for the Inlet Throat, Nixon Channel, and Green Channel.

**TABLE 11-11**

**TIDAL PRISM ESTIMATES**
**DELFT3D MODEL**
**FIGURE EIGHT ISLAND, NC**

| Years | Average Tidal Prism ± 1 standard deviation (cubic feet) | | |
|---|---|---|---|
| | Inlet Throat | Nixon Channel | Green Channel |
| | Alternative 2: Abandon/Retreat | | |
| 0-1 | 674,963,000 ± 14,277,000 | 320,038,000 ± 6,285,000 | 251,237,000 ± 3,681,000 |
| 1-2 | 688,097,000 ± 12,558,000 | 316,996,000 ± 6,113,000 | 256,358,000 ± 5,136,000 |
| 2-3 | 673,596,000 ± 16,185,000 | 308,621,000 ± 5,331,000 | 251,251,000 ± 4,665,000 |
| 3-4 | 612,048,000 ± 24,888,000 | 314,217,000 ± 10,891,000 | 248,895,000 ± 5,289,000 |
| 4-5 | 589,155,000 ± 16,826,000 | 309,384,000 ± 6,633,000 | 241,639,000 ± 6,067,000 |
| | Alternative 3: Rich Inlet Management and Beach Fill | | |
| 0-1 | 666,228,000 ± 17,634,000 | 345,415,000 ± 5,110,000 | 232,758,000 ± 3,143,000 |
| 1-2 | 666,731,000 ± 15,324,000 | 350,208,000 ± 6,700,000 | 227,414,000 ± 4,890,000 |
| 2-3 | 639,554,000 ± 14,521,000 | 341,503,000 ± 6,314,000 | 227,128,000 ± 6,919,000 |
| 3-4 | 642,872,000 ± 13,028,000 | 339,846,000 ± 9,506,000 | 239,510,000 ± 20,015,000 |
| 4-5 | 638,468,000 ± 12,018,000 | 344,953,000 ± 6,704,000 | 241,414,000 ± 20,726,000 |
| | Alternative 4: Beach Fill without Management of Rich Inlet | | |
| 0-1 | 678,485,000 ± 15,828,000 | 322,498,000 ± 5,874,000 | 251,483,000 ± 3,920,000 |
| 1-2 | 692,236,000 ± 11,725,000 | 318,773,000 ± 6,670,000 | 256,401,000 ± 5,305,000 |
| 2-3 | 679,974,000 ± 11,450,000 | 309,579,000 ± 4,855,000 | 252,731,000 ± 4,149,000 |
| 3-4 | 660,426,000 ± 14,716,000 | 301,055,000 ± 7,674,000 | 248,910,000 ± 4,533,000 |
| 4-5 | 624,278,000 ± 39,969,000 | 311,926,000 ± 9,393,000 | 240,196,000 ± 7,015,000 |
| | Alternative 5A: Terminal Groin with Beach Fill from Nixon Channel (700 foot groin) | | |
| 0-1 | 661,590,000 ± 11,281,000 | 334,459,000 ± 4,810,000 | 237,804,000 ± 3,791,000 |
| 1-2 | 669,388,000 ± 12,643,000 | 331,467,000 ± 5,999,000 | 240,134,000 ± 3,886,000 |
| 2-3 | 630,885,000 ± 35,673,000 | 341,117,000 ± 9,872,000 | 235,344,000 ± 3,799,000 |
| 3-4 | 576,735,000 ± 16,105,000 | 332,656,000 ± 6,915,000 | 234,187,000 ± 4,287,000 |
| 4-5 | 583,359,000 ± 25,649,000 | 329,190,000 ± 5,292,000 | 229,599,000 ± 5,708,000 |

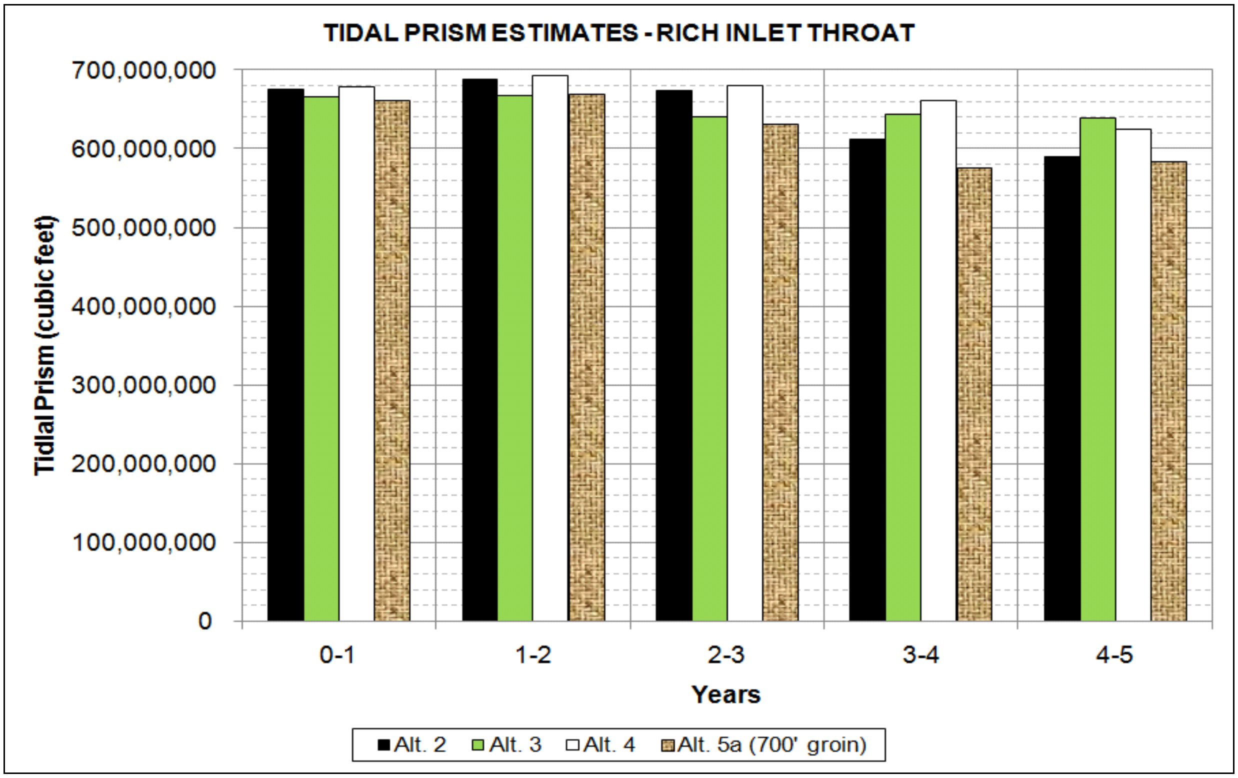


**FIGURE 11-54: Tidal Prism in Rich Inlet as a Whole.**

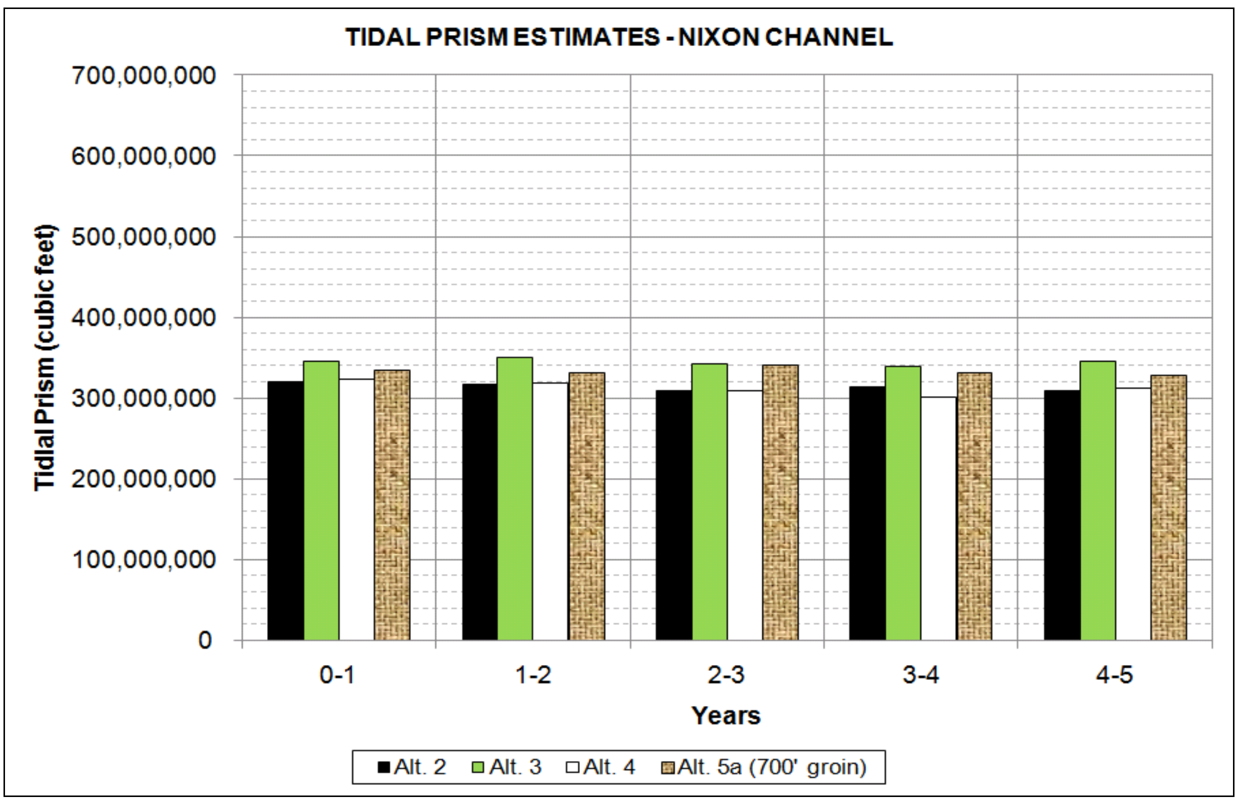


**FIGURE 11-55: Tidal Prism in Nixon Channel.**

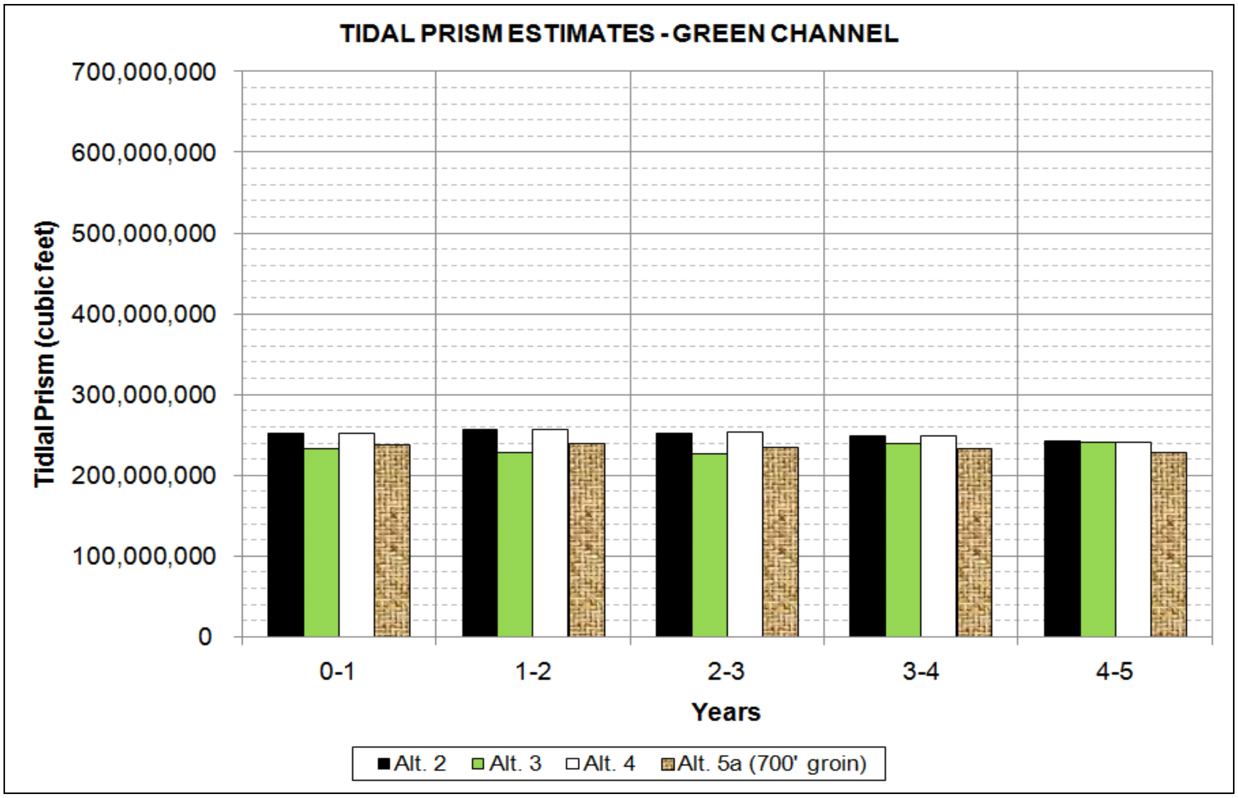


**FIGURE 11-56: Tidal Prism in Green Channel.**

Over the 5-year simulation period, the total tidal prism of the inlet throat decreases for each alternative, including Alternative 2, which represents the without project condition. The relative changes in tidal prism for the three channels are provided in Table 11-12 which gives the percent of flow in simulation years 4-5 relative to the flow in years 0-1. The changes in the tidal prism for Alternative 2 are associated with predicted changes in the inlet morphology generated by the Delft3D model that would occur under existing conditions. The predicted decrease in the inlet's tidal prism over the 5-year simulation period for Alternative 3 appears to be significantly less than the other alternatives. This is not unexpected given the excavation of the new ocean bar channel and new channel connectors into Nixon and Green Channels. The reduction in tidal prism associated with Alternative 4 also appears to be less than Alternative 2; however this difference can be attributed to computational externalities in interpreting the Delft3D model results across each of the flow transects.

**TABLE 11-12**

**RELATIVE CHANGE IN TIDAL PRISM OVER THE 5-YEAR SIMULATION PERIOD[1]**
**BASED ON DELFT3D MODEL**

| Alternative | Inlet Throat | Nixon Channel | Green Channel |
|---|---|---|---|
| 2 | 87.3% | 96.7% | 96.2% |
| 3 | 95.8% | 99.9% | 103.7% |
| 4 | 92.0% | 96.7% | 95.5% |
| 5A | 88.2% | 98.4% | 96.5% |

[1] Average flow in year 4-5 divided by flow in year 0-1 expressed as percent.

Table 11-13 provides the change in tidal prism in each year of the simulations through the Inlet Throat, Nixon Channel, and Green Channel relative to the tidal prism determined for Alternative 2 in each year. For the most part, computed changes in the total tidal prism of Nixon Inlet (represented by the Inlet Throat) for all of the alternatives differ by about ±5% and are not deemed to be significant given the inherent variability associated with flow computations derived from the results of the Delft3D simulations.

**TABLE 11-13**

**CHANGE IN TIDAL PRISM IN THE INLET THROAT, NIXON CHANNEL, AND GREEN CHANNEL RELATIVE TO ALTERNATIVE 2**
**DELFT3D MODEL**
**FIGURE EIGHT ISLAND, NC**

| Years | Inlet Throat | Nixon Channel | Green Channel |
|---|---|---|---|
| Alternative 3: Rich Inlet Management and Beach Fill | | | |
| 0-1 | 98.7% | 107.9% | 92.6% |
| 1-2 | 96.9% | 110.5% | 88.7% |
| 2-3 | 94.9% | 110.7% | 90.4% |
| 3-4 | 105.0% | 108.2% | 96.2% |
| 4-5 | 108.4% | 111.5% | 99.9% |
| Average | 100.8% | 109.7% | 93.6% |
| Alternative 4: Beach Fill without Management of Rich Inlet | | | |
| 0-1 | 100.5% | 100.8% | 100.1% |
| 1-2 | 100.6% | 100.6% | 100.0% |
| 2-3 | 100.9% | 100.3% | 100.6% |
| 3-4 | 107.9% | 95.8% | 100.0% |
| 4-5 | 106.0% | 100.8% | 99.4% |
| Average | 103.2% | 99.7% | 100.0% |
| Alternative 5A: Terminal Groin with Beach Fill from Nixon Channel (700 foot groin) | | | |
| 0-1 | 98.0% | 104.5% | 94.7% |
| 1-2 | 97.3% | 104.6% | 93.7% |
| 2-3 | 93.7% | 110.5% | 93.7% |
| 3-4 | 94.2% | 105.9% | 94.1% |
| 4-5 | 99.0% | 106.4% | 95.0% |
| Average | 96.4% | 106.4% | 94.2% |

The distributions of flows into Nixon and Green Channels expressed as a percent of flow passing through the inlet throat during each year of the simulations for Alternatives 2, 3, 4, and 5A are provided in Table 11-14.

**TABLE 11-14**

**DISTRIBUTION OF FLOW IN NIXON AND GREEN CHANNELS AS A PERCENT OF THE TOTAL FLOW PASSING THROUGH THE INLET THROAT**
**DELFT3D MODEL**
**FIGURE EIGHT ISLAND, NC**

| Years | Nixon Channel | Green Channel |
|---|---|---|
| Alternative 2: Without Project | | |
| 0-1 | 47.4% | 37.2% |
| 1-2 | 46.1% | 37.3% |
| 2-3 | 45.8% | 37.3% |
| 3-4 | 51.3% | 40.7% |
| 4-5 | 52.5% | 41.0% |
| Average | 48.6% | 38.7% |
| Alternative 3: Rich Inlet Management and Beach Fill | | |
| 0-1 | 51.8% | 34.9% |
| 1-2 | 52.5% | 34.1% |
| 2-3 | 53.4% | 35.5% |
| 3-4 | 52.9% | 37.3% |
| 4-5 | 54.0% | 37.8% |
| Average | 52.9% | 35.9% |
| Alternative 4: Beach Fill without Management of Rich Inlet | | |
| 0-1 | 47.5% | 37.1% |
| 1-2 | 46.0% | 37.0% |
| 2-3 | 45.5% | 37.2% |
| 3-4 | 45.6% | 37.7% |
| 4-5 | 50.0% | 38.5% |
| Average | 46.9% | 37.5% |
| Alternative 5A: Terminal Groin with Beach Fill from Nixon Channel (700 foot groin) | | |
| 0-1 | 50.6% | 35.9% |
| 1-2 | 49.5% | 35.9% |
| 2-3 | 54.1% | 37.3% |
| 3-4 | 57.7% | 40.6% |
| 4-5 | 56.4% | 39.4% |
| Average | 53.7% | 37.8% |

Under existing conditions represented by Alternative 2, over the 5-year simulation period, an average of about 49% of the flow passing through the inlet throat passed through Nixon Channel and roughly 39% passed through Green Channel. The balance of the flow, approximately 12%, moved through the marsh areas situated immediately behind (i.e., north of) the inlet throat. For Alternative 3, which includes a relatively large channel connector between the inlet gorge and Nixon Channel, flow through Nixon Channel increased to around 53% while the flow through Green Channel reduced to about 36%. Again the balance of the flow, 11% in this case, moved through the marsh areas.

Alternative 4, which had the same initial inlet conditions as Alternative 2 but did include a beach fill along Figure Eight Island, the flow distribution through Nixon and Green Channels was essentially the same as Alternative 2 with 47% passing through Nixon Channel and 38% through Green Channel.

Alternative 5A, which includes a terminal groin on the north end of Figure Eight Island, beach fill, and a channel connecting the inlet gorge with Nixon Channel, had 54% of the flow going through Nixon Channel and 38% through Green Channel which was similar to Alternative 3. Since both Alternatives 3 and 5A included the connector channel into Nixon Channel, the similar flow distributions was not unexpected.

Alternative 5B was not directly simulated in the Delft3D model. However, since this alternative only includes a terminal groin on the north end of Figure Eight Island and beach fill using material from the existing permit area in Nixon Channel but would not involve any modifications to the interior channels, the distribution of flow through Nixon and Green Channels can be inferred from the results observed for Alternatives 2 and 4. The results for Alternatives 2 and 4 indicate around 47% to 49% of the total flow would be expected to pass through Nixon Channel and between 38% and 39% through Green Channel given Alternative 5B.

### 11.5 Primary and Secondary Impact Areas

The primary impact areas under Alternatives 3, 5A, and 5B are defined by the dredge area and the fill areas, including the closure dike. These areas represent the zones that will be directly impacted by dredging and fill placement. Primary impact areas appear in Table 11-15:

**TABLE 11-15**

**PRIMARY IMPACT AREAS**

| AREA | acres |
|---|---|
| ALTERNATIVE 3: | |
| Dredge Area | 92.3 |
| Closure Dike | 36.5 |
| Oceanfront Beach Disposal Area | 132.5 |
| Nixon Channel Beach Disposal Area | 7.4 |
| TOTAL | 268.7 |
| ALTERNATIVE 5A: | |
| Dredge Area | 86.7 |
| Oceanfront Beach Disposal Area | 116.7 |
| Nixon Channel Beach Disposal Area | 7.4 |
| Terminal Groin Footprint | 1.1 |
| TOTAL | 211.9 |

**TABLE 11-15 (continued)**

**PRIMARY IMPACT AREAS**

| AREA | acres |
|---|---|
| ALTERNATIVE 5B: | |
| Dredge Area | 44.7 |
| Oceanfront Beach Disposal Area | 77.0 |
| Nixon Channel Beach Disposal Area | 7.4 |
| Terminal Groin Footprint | 1.1 |
| TOTAL | 130.2 |

Secondary impact areas are based on the Delft3D model results and the equilibrium toes of beach fill. To accommodate uncertainty regarding the model results, two acreage values were estimated for the secondary impact area:

1. The areas under which the vertical difference between the with-project and without-project (Alt. 2) surfaces at Year 5 (Figures 11-43, 11-48, and 11-52) is greater than 0.5 feet. These areas are marked by the pink lines in Figures 11-57 and 11-58. The secondary impact area based on this estimate is:

   a. 1,769 acres under Alternative 3.
   b. 1,359 acres for Alternatives 5A and 5B.

2. The areas within the pink lines in Figures 11-57 and 11-58 or the equilibrium toes of beach fill (blue dashed lines). The secondary impact area based on this estimate is:

   a. 1,899 acres Alternative 3.
   b. 1,548 acres for Alternatives 5A and 5B.

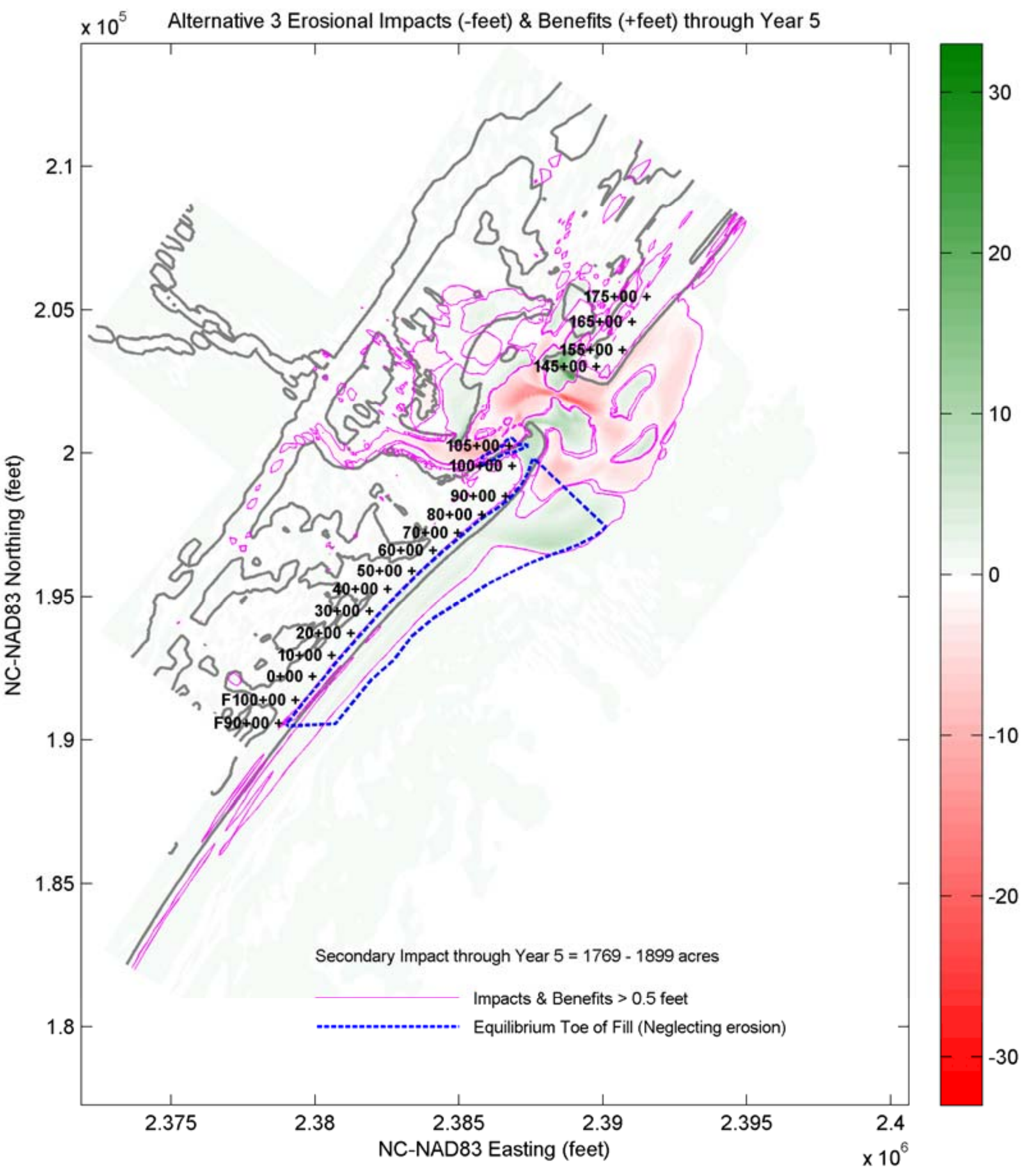


**FIGURE 11-57: 5-Year Secondary Impact Areas, Alternative 3.**

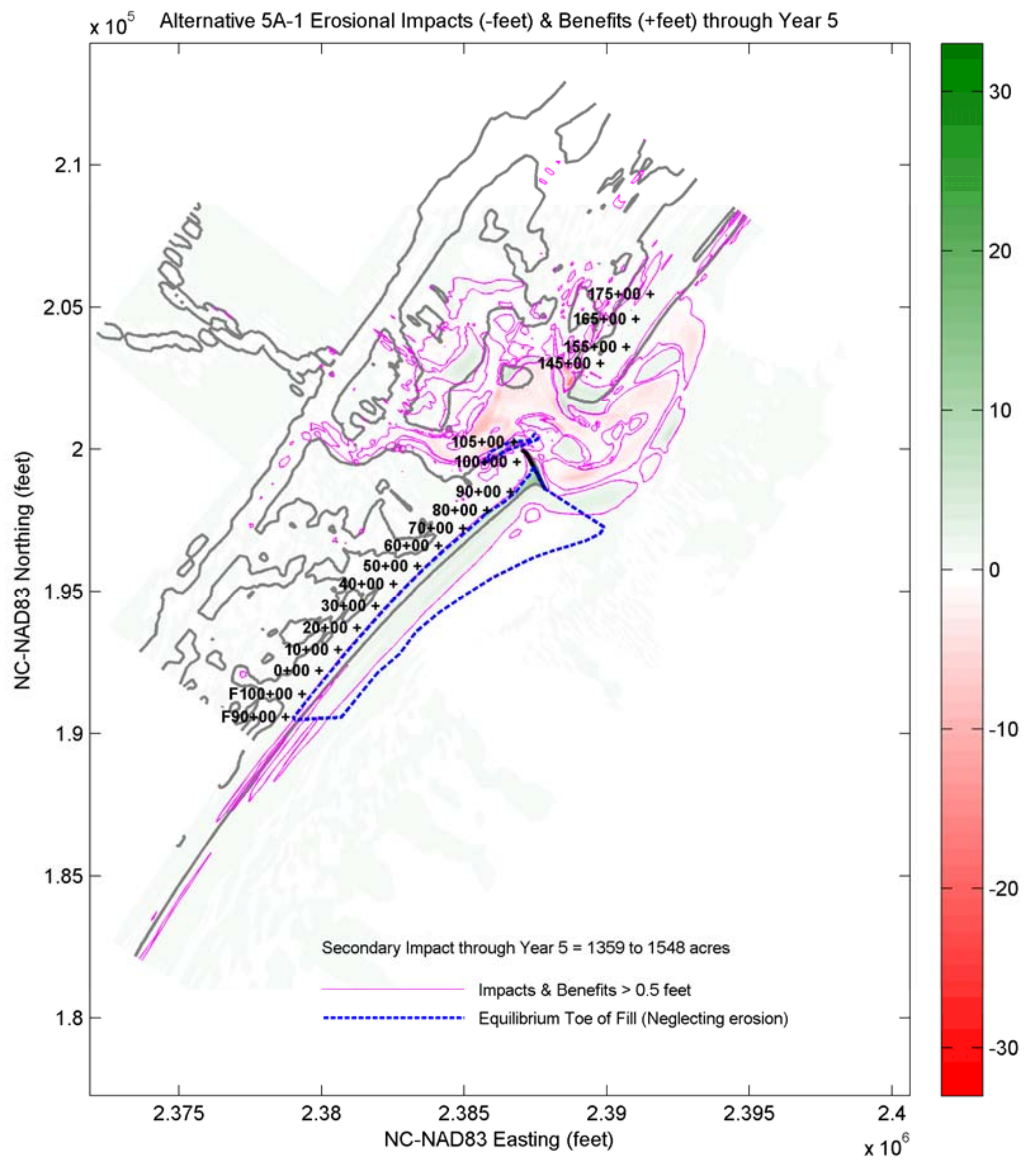


**FIGURE 11-58: 5-Year Secondary Impact Areas, Alternative 5A and 5B.**

## 12.0 OCEANFRONT BEACH FILL PERFORMANCE BASED ON THE GENESIS MODEL

### 12.1 Background

To provide a "second opinion" regarding the performance and impact of the channel modification and terminal groin alternatives, this Shoreline Management study utilizes the Generalized Model for Simulating Shoreline Change (GENESIS). GENESIS can incorporate the effects of groins, revetments, seawalls, breakwaters, and offshore bathymetry. Inputs to the model include shoreline locations, structure locations, a time series of offshore waves, and, if desired, a set of wave refraction coefficients and refracted wave angles.

GENESIS determines shoreline changes relative to a fixed baseline based on the wave-driven, longshore sediment transport. The model assumes that shoreline change is directly proportional to volume change, the profile shape is relatively constant with time, the berm elevation is uniform, and the depth of closure is uniform. As such, it is a "one-line" model that calculates shoreline position rather than bathymetric changes. The primary advantage of the GENESIS model is its ability to rapidly simulate (1-5 minutes) long-term (5-20 year) shoreline changes using a narrow grid spacing (10-50 feet).

Transport rates are calculated using the USACE (1990) formula (CERC Equation), with an additional term to account for longshore variations in the breaking wave height. To calibrate the model, three longshore transport coefficients are determined:

1. Coefficient K1 governs the transport resulting from changes in the shoreline orientation. K1 typically ranges from 0.1 to 2 and has the largest influence on the model's results (Hanson and Kraus, 1991; CPE, 2007). If GENESIS is being used with a wave transformation model that includes bottom friction, the K1 values tend to be larger.

2. Coefficient K2 governs the transport resulting from variations in the breaking wave height (Hanson and Kraus, 1991). K2 typical ranges from 0 to the value of K1.

The GENESIS baseline for Figure Eight Island appears in Figure 12-1. The baseline extends from profile F0+00 near the south end of Beach Road to profile 110+00 near Rich Inlet. The length of the baseline is 22,000 feet, with a grid spacing of 25 feet. The purpose of the long baseline is to accommodate the spreading of beach fill material given the placement of beach fill between 8 Beach Road S and Rich Inlet (profiles F90+00 to 110+00).

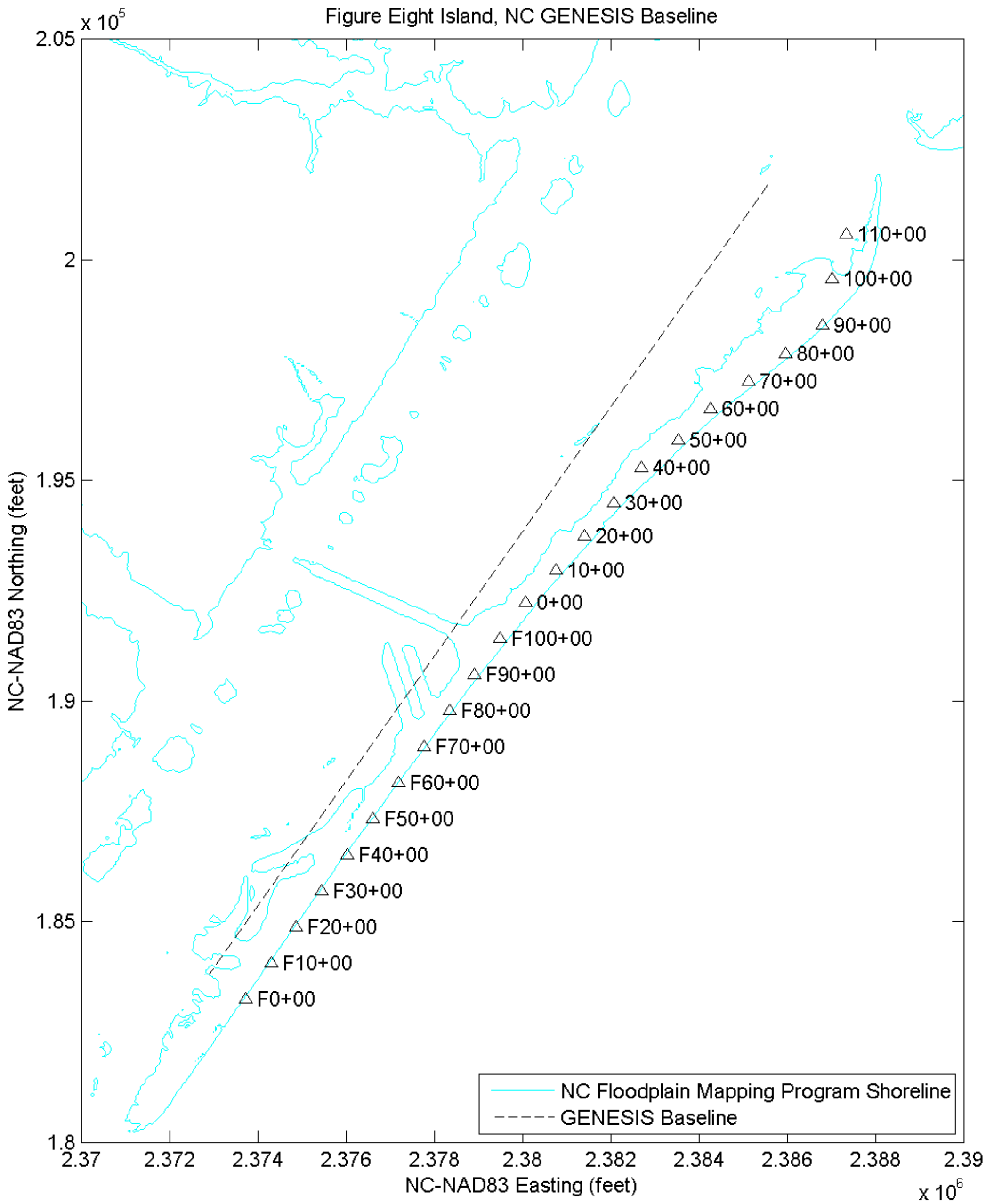


**FIGURE 12-1: Figure Eight Island, NC GENESIS Baseline.**

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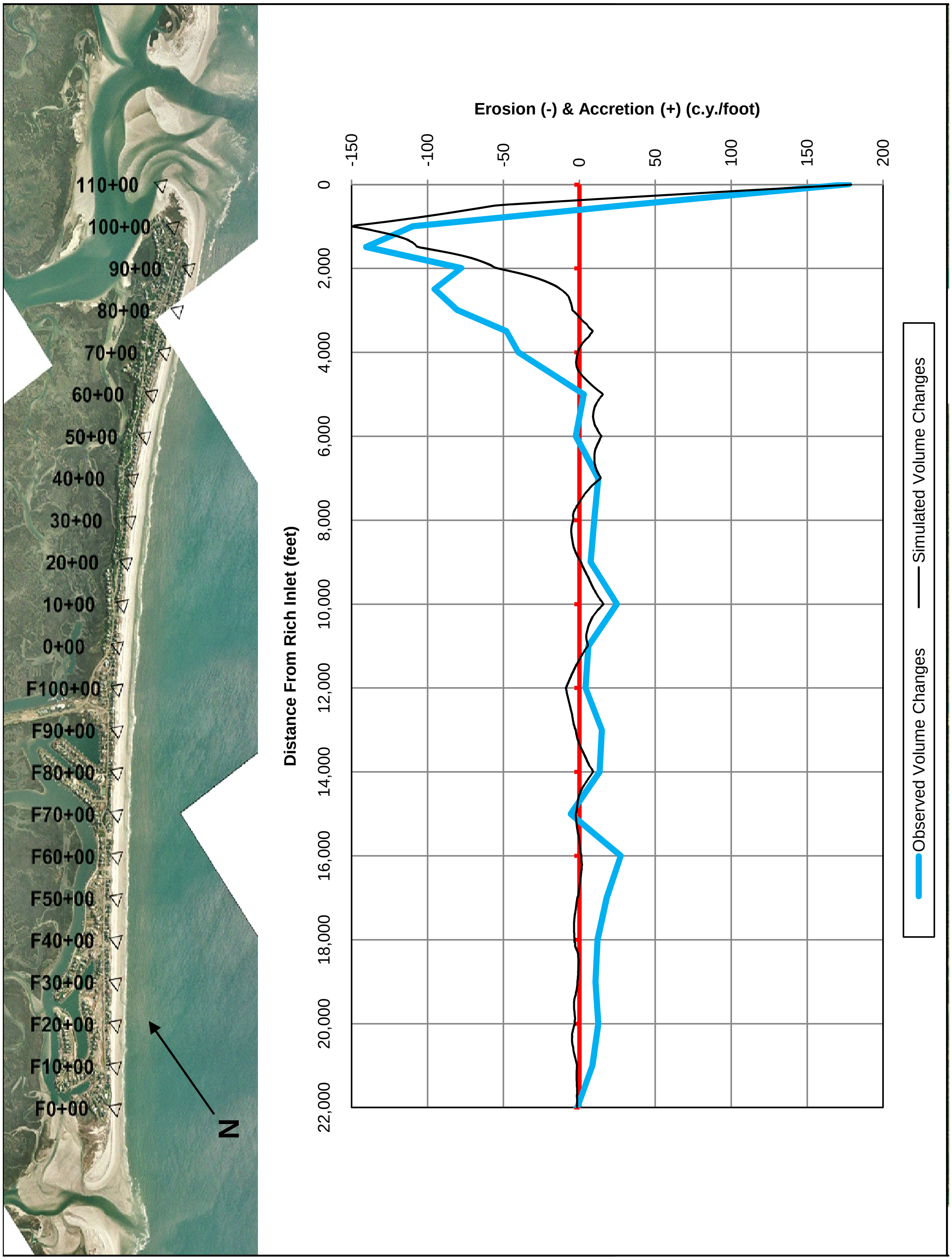


**FIGURE 12-2: GENESIS Model Calibration, April 2007 to October 2008.**

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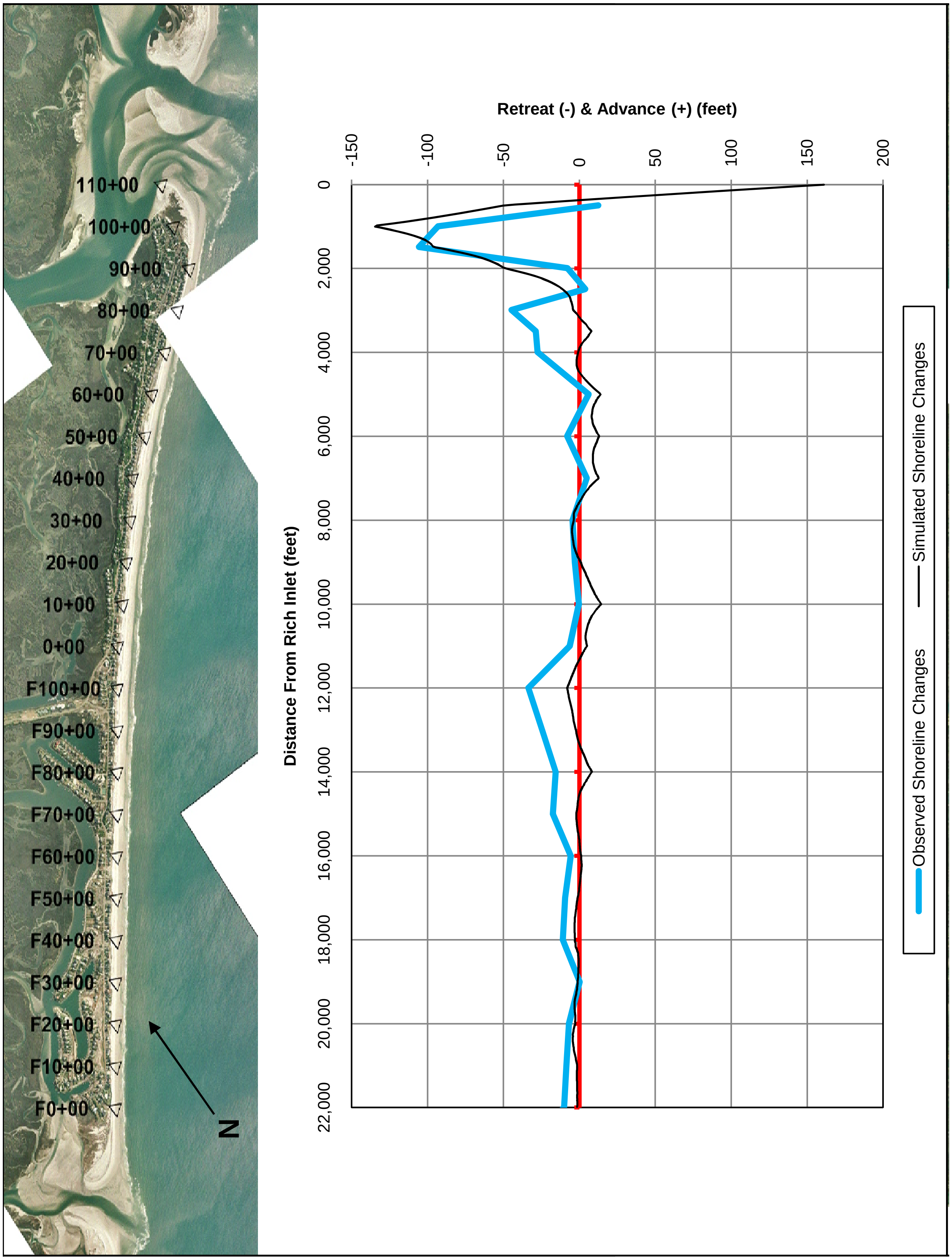


**FIGURE 12-3: GENESIS Model Calibration, April 2007 to October 2008.**

## 12.2 Wave Data

The wave data used in the GENESIS model was taken from the NOAA Western North Atlantic Wavewatch forecast at 34.00ºN, 76.25ºW, -644 feet NAVD (see Figure 11-12). This location was the same forecast node used in the Delft3D calibration. The record at this site extended from July 1, 1999 to May 31, 2010.

To determine the nearshore waves, the wave record was divided into the following wave height, period, and direction classes:

- Significant wave height classes: 0 to 6.4 feet, 6.4 to 10 feet, 10 to 35 feet.
- Peak wave period classes: 0-5 seconds, 5-7 seconds, 7-9 seconds, 9-11 seconds, 11-13 seconds, 13-15 seconds, 15-17 seconds, 17-23 seconds.
- Wave direction classes: 35-58°, 58-80°, 80-103°, 103-125°, 125-148°, 148-170°, 170-193°, 193-215°.

Each wave height classes contained an equal amount of wave energy in KW-Hours/m (see Section 11.3.2). The wave period and direction classes were based on typical divisions used in GENESIS modeling studies. Although the divisions above created 192 height, period, and direction classes, only 127 actually contained wave data. The average wave in each class (Table 12-1) was then transformed to the depth of closure (-24 feet NAVD) using the SWAN model. Refraction coefficients were then calculated based on the ratios of the transformed wave heights to the offshore wave heights in Table 12-1. The grids, bathymetries, and parameters used in the SWAN model were identical to those in Table 11-6 and Figures 11-10 to 11-15.

## 12.3 Model Calibration

The calibration of the GENESIS model was based on the shoreline and volume changes between April 2007 and October 2008. The April 2007 shoreline was used as the initial condition. A berm elevation of +6 feet NAVD was assumed, along with a closure depth of -24 feet NAVD and an average grain size of 0.18 mm (see Table 4-7). The sandbags along the north end of the island were neglected. When these were included in the model as a "seawall", their effect was grossly overstated.

To determine the values of K1 and K2, several GENESIS runs were performed using K1 values ranging from 2 to 7. The best results were achieved by setting K1 equal to 2. Changing the value of K2 from 0 to 2 led to smoother shoreline and volume changes with respect to distance. It also provided for better results when the proposed groin was included in subsequent simulations (see Hanson and Kraus, 1991, p. 53).

In general, the agreement between the simulated and observed changes was good (Figures 12-2 and 12-3).

## TABLE 12-1

## WAVE CASES FOR GENESIS MODEL

| Case # | Hs (feet) | Tp (sec.) | Dir. (°) |
|---|---|---|---|
| 10101 | 4.1 | 4.4 | 46 |
| 20101 | 4.1 | 4.4 | 69 |
| 30101 | 4.1 | 4.4 | 91 |
| 40101 | 4.1 | 4.4 | 114 |
| 50101 | 4.1 | 4.4 | 136 |
| 60101 | 4.1 | 4.4 | 159 |
| 70101 | 4.1 | 4.4 | 181 |
| 80101 | 4.1 | 4.4 | 204 |
| 10201 | 4.1 | 6.0 | 46 |
| 20201 | 4.1 | 6.0 | 69 |
| 30201 | 4.1 | 6.0 | 91 |
| 40201 | 4.1 | 6.0 | 114 |
| 50201 | 4.1 | 6.0 | 136 |
| 60201 | 4.1 | 6.0 | 159 |
| 70201 | 4.1 | 6.0 | 181 |
| 80201 | 4.1 | 6.0 | 204 |
| 10301 | 4.1 | 8.0 | 46 |
| 20301 | 4.1 | 8.0 | 69 |
| 30301 | 4.1 | 8.0 | 91 |
| 40301 | 4.1 | 8.0 | 114 |
| 50301 | 4.1 | 8.0 | 136 |
| 60301 | 4.1 | 8.0 | 159 |
| 70301 | 4.1 | 8.0 | 181 |
| 80301 | 4.1 | 8.0 | 204 |
| 10401 | 4.1 | 9.8 | 46 |
| 20401 | 4.1 | 9.8 | 69 |
| 30401 | 4.1 | 9.8 | 91 |
| 40401 | 4.1 | 9.8 | 114 |
| 50401 | 4.1 | 9.8 | 136 |
| 60401 | 4.1 | 9.8 | 159 |
| 70401 | 4.1 | 9.8 | 181 |
| 10501 | 4.1 | 11.7 | 46 |
| 20501 | 4.1 | 11.7 | 69 |
| 30501 | 4.1 | 11.7 | 91 |
| 40501 | 4.1 | 11.7 | 114 |
| 50501 | 4.1 | 11.7 | 136 |
| 10601 | 4.1 | 13.7 | 46 |
| 20601 | 4.1 | 13.7 | 69 |
| 30601 | 4.1 | 13.7 | 91 |
| 40601 | 4.1 | 13.7 | 114 |
| 50601 | 4.1 | 13.7 | 136 |
| 20701 | 4.1 | 15.6 | 69 |
| 40701 | 4.1 | 15.6 | 114 |
| 50701 | 4.1 | 15.6 | 136 |
| 10102 | 7.8 | 4.4 | 46 |
| 50102 | 7.8 | 4.4 | 136 |
| 60102 | 7.8 | 4.4 | 159 |
| 70102 | 7.8 | 4.4 | 181 |
| 80102 | 7.8 | 4.4 | 204 |
| 10202 | 7.8 | 6.0 | 46 |
| 20202 | 7.8 | 6.0 | 69 |
| 30202 | 7.8 | 6.0 | 91 |
| 40202 | 7.8 | 6.0 | 114 |
| 50202 | 7.8 | 6.0 | 136 |
| 60202 | 7.8 | 6.0 | 159 |
| 70202 | 7.8 | 6.0 | 181 |
| 80202 | 7.8 | 6.0 | 204 |

| Case # | Hs (feet) | Tp (sec.) | Dir. (°) |
|---|---|---|---|
| 10302 | 7.8 | 8.0 | 46 |
| 20302 | 7.8 | 8.0 | 69 |
| 30302 | 7.8 | 8.0 | 91 |
| 40302 | 7.8 | 8.0 | 114 |
| 50302 | 7.8 | 8.0 | 136 |
| 60302 | 7.8 | 8.0 | 159 |
| 70302 | 7.8 | 8.0 | 181 |
| 80302 | 7.8 | 8.0 | 204 |
| 10402 | 7.8 | 9.8 | 46 |
| 20402 | 7.8 | 9.8 | 69 |
| 30402 | 7.8 | 9.8 | 91 |
| 40402 | 7.8 | 9.8 | 114 |
| 50402 | 7.8 | 9.8 | 136 |
| 60402 | 7.8 | 9.8 | 159 |
| 70402 | 7.8 | 9.8 | 181 |
| 80402 | 7.8 | 9.8 | 204 |
| 10502 | 7.8 | 11.7 | 46 |
| 20502 | 7.8 | 11.7 | 69 |
| 30502 | 7.8 | 11.7 | 91 |
| 40502 | 7.8 | 11.7 | 114 |
| 50502 | 7.8 | 11.7 | 136 |
| 60502 | 7.8 | 11.7 | 159 |
| 70502 | 7.8 | 11.7 | 181 |
| 80502 | 7.8 | 11.7 | 204 |
| 10602 | 7.8 | 13.7 | 46 |
| 20602 | 7.8 | 13.7 | 69 |
| 30602 | 7.8 | 13.7 | 91 |
| 40602 | 7.8 | 13.7 | 114 |
| 50602 | 7.8 | 13.7 | 136 |
| 60602 | 7.8 | 13.7 | 159 |
| 20702 | 7.8 | 15.6 | 69 |
| 40702 | 7.8 | 15.6 | 114 |
| 40802 | 7.8 | 17.4 | 114 |
| 10203 | 12.2 | 6.0 | 46 |
| 20203 | 12.2 | 6.0 | 69 |
| 30203 | 12.2 | 6.0 | 91 |
| 40203 | 12.2 | 6.0 | 114 |
| 50203 | 12.2 | 6.0 | 136 |
| 60203 | 12.2 | 6.0 | 159 |
| 70203 | 12.2 | 6.0 | 181 |
| 80203 | 12.2 | 6.0 | 204 |
| 10303 | 12.2 | 8.0 | 46 |
| 20303 | 12.2 | 8.0 | 69 |
| 30303 | 12.2 | 8.0 | 91 |
| 40303 | 12.2 | 8.0 | 114 |
| 50303 | 12.2 | 8.0 | 136 |
| 60303 | 12.2 | 8.0 | 159 |
| 70303 | 12.2 | 8.0 | 181 |
| 80303 | 12.2 | 8.0 | 204 |
| 10403 | 12.2 | 9.8 | 46 |
| 20403 | 12.2 | 9.8 | 69 |
| 30403 | 12.2 | 9.8 | 91 |
| 40403 | 12.2 | 9.8 | 114 |
| 50403 | 12.2 | 9.8 | 136 |
| 60403 | 12.2 | 9.8 | 159 |
| 70403 | 12.2 | 9.8 | 181 |
| 80403 | 12.2 | 9.8 | 204 |

**TABLE 12-1 (continued)**

**WAVE CASES FOR GENESIS MODEL**

| Case # | Hs (feet) | Tp (sec.) | Dir. (°) |
|---|---|---|---|
| 10503 | 12.2 | 11.7 | 46 |
| 20503 | 12.2 | 11.7 | 69 |
| 50503 | 12.2 | 11.7 | 136 |
| 60503 | 12.2 | 11.7 | 159 |
| 70503 | 12.2 | 11.7 | 181 |
| 20603 | 12.2 | 13.7 | 69 |
| 30603 | 12.2 | 13.7 | 91 |
| 40603 | 12.2 | 13.7 | 114 |
| 50603 | 12.2 | 13.7 | 136 |
| 60603 | 12.2 | 13.7 | 159 |
| 70603 | 12.2 | 13.7 | 181 |
| 40703 | 12.2 | 15.6 | 114 |
| 50703 | 12.2 | 15.6 | 136 |

The only exception was the area between Surf Court and Comber Road (profiles 65+00 to 90+00), where the model predicted a stable beach instead of an eroding beach. At all other locations, the model results were generally consistent with the observed shoreline and volume changes.

## 12.4 Model Verification

The verification of the GENESIS model was based on the shoreline and volume changes between April 2006 and April 2007. This period was preceded by beach fill operations on the northern and southern thirds of the island (see Table 6-2). Observed volume change patterns were characterized by an erosion hotspot on the north end of the island, stability in the middle of the island, and erosion on the southern third of the island. The April 2006 shoreline was used as the initial condition on the northern half of the island, and the June 2006 shoreline was used as the initial condition on the southern half of the island. The values of K1 and K2 were identical to those used in the final calibration run, and the existing sandbags were neglected.

Along most of Figure Eight Island, shoreline changes during the verification period were characterized by the change in the beach profile shape following the various beach fill operations (see Figure 12-5). Since this process was not included in the GENESIS model, differences between the simulated and observed shoreline changes occurred in several locations. However, on the northern and central sections of the island, agreement between the simulated and observed volume changes was good (Figure 12-4). The overall volume change patterns that occurred between April 2006 and April 2007 were reproduced by the model. On the southern third of the island (profiles F0+00 to F70+00), the GENESIS model tended to predict stable beaches instead of eroding beaches. This was due to the fact that the waves and tidal currents in Mason Inlet were not incorporated into the SWAN and GENESIS models.

Overall the calibration and verification showed that the GENESIS model is able to simulate the observed shoreline and volume changes after the beach profiles have adjusted to their equilibrium shape. During the initial adjustment period, which ranges from 1-3 years, the GENESIS model is best used as a volume change model. Based on the results presented in Figures 12-2 to 12-5, the GENESIS model is suitable for providing a “second opinion” regarding

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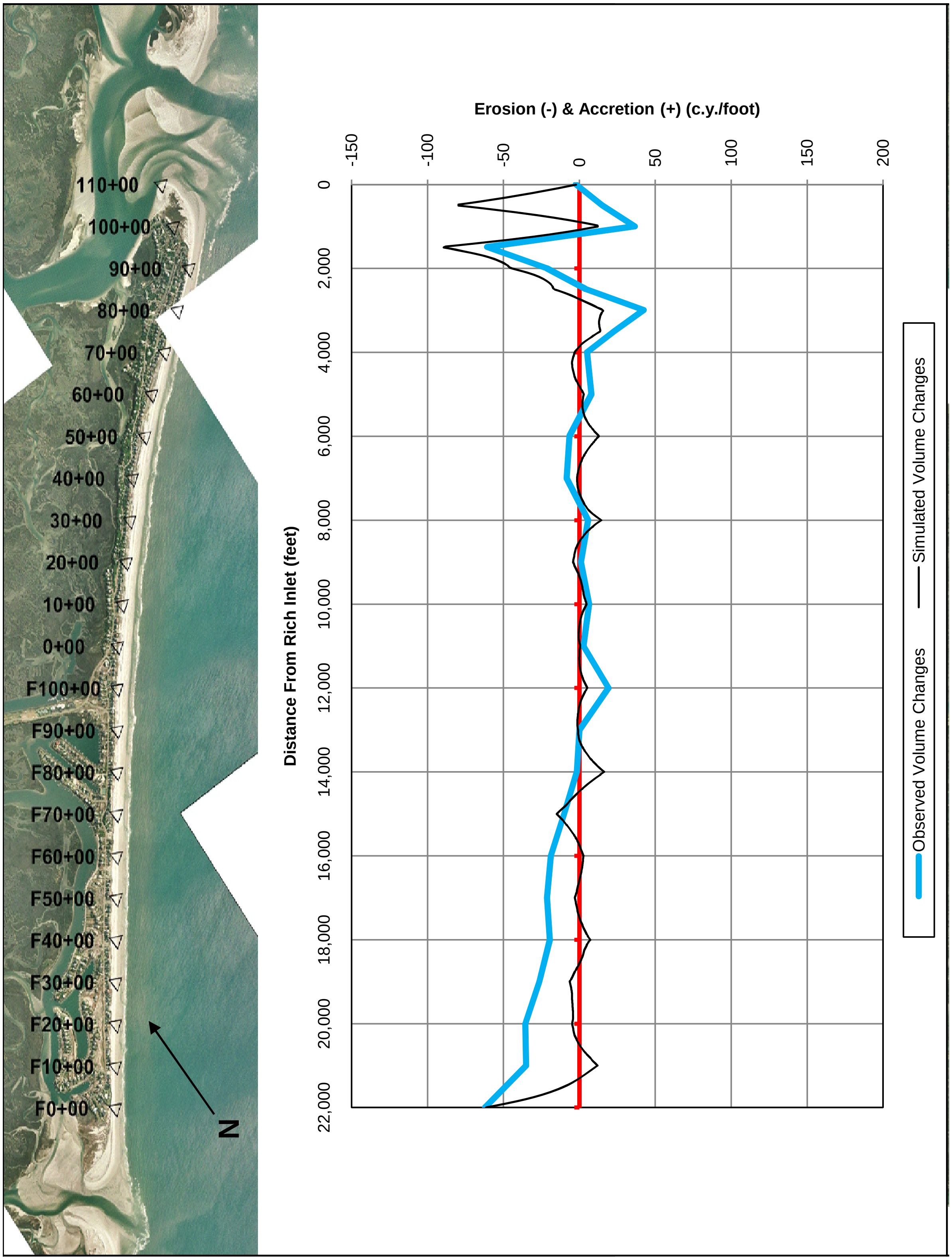


**FIGURE 12-4: GENESIS Model Verification, April 2006 to April 2007.**

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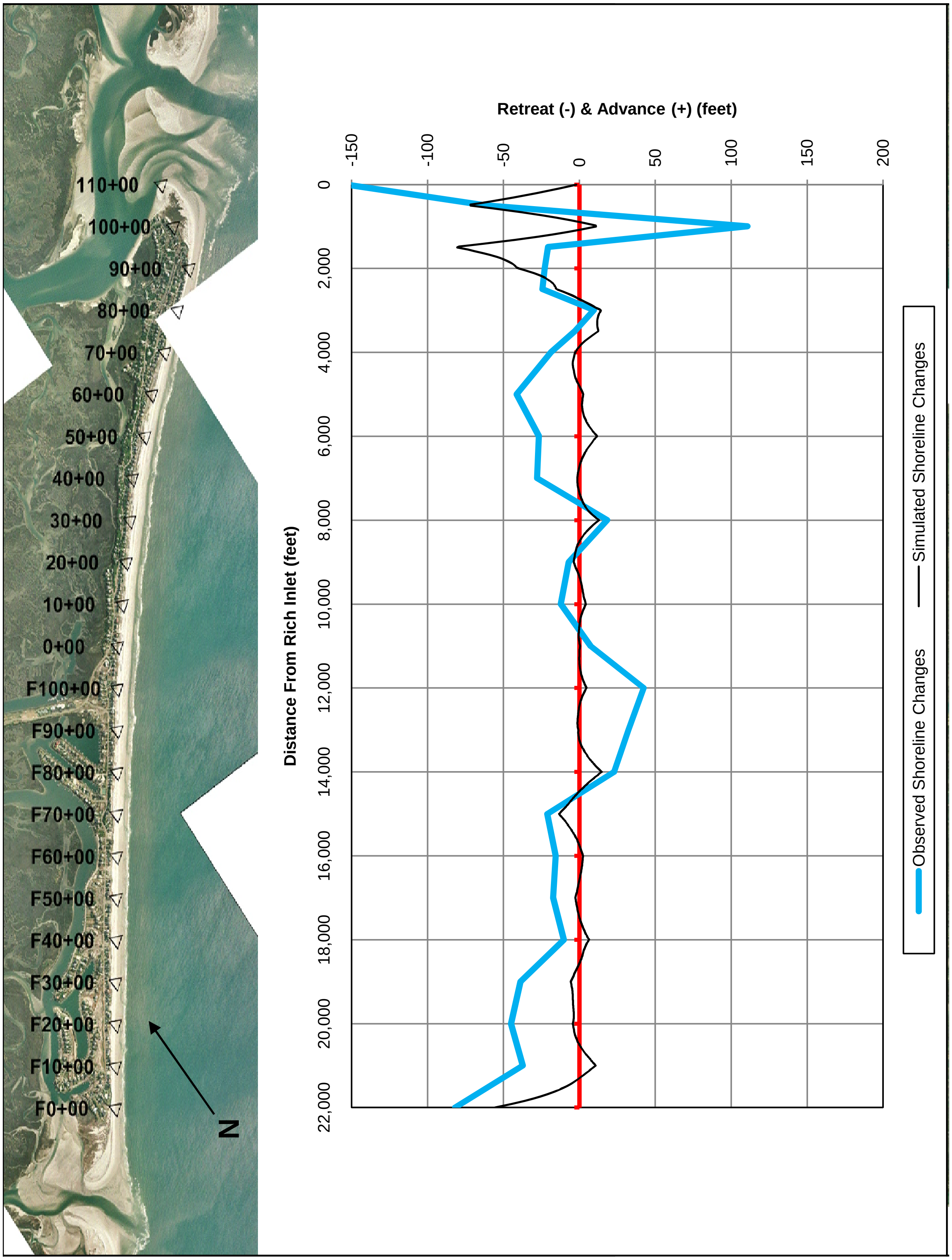


**FIGURE 12-5: GENESIS Model Verification, April 2006 to April 2007.**

beach fill performance over a 5 year beach and inlet maintenance cycle on the northern and middle sections of Figure Eight Island.

### 12.5 Future Conditions

To estimate future shoreline changes, 3 alternatives were simulated:

- Alternative 2 – Abandon/Retreat. As noted in the main report, this alternative can be considered the Without-Project scenario.

- Alternative 3 – Rich Inlet Management and Beach Fill.

- Alternative 5A – Terminal Groin with Beach Fill from Nixon Channel.

- Alternative 5B - Terminal Groin with Beach Fill from Maintenance of the Existing Navigation Channel and Other Sources.

Since the beach fills for Alternatives 3, 5A, and 5B were design based, (see Figures 9-13, 9-25, and 9-25), the April 2007 survey was used as the initial condition for Alternative 2. To account for the adjustment of the beach profile shape following construction, the initial conditions for Alternatives 3 and 5A utilized an "equilibrium shoreline" along the respective beach fill areas. The offsets between the equilibrium shoreline and the April 2007 shoreline were proportional to the beach fill distributions in Tables 9-2 ($5^{th}$ column) and 9-5 ($4^{th}$ column).

To account for risk and uncertainty, 10 runs were performed for each scenario using random sequences of annual waves (Table 12-2). An additional run was then conducted using the actual wave sequence between 2000 and 2010, for a total of 11 runs. To provide information regarding long-term changes, the duration of each simulation was 10 years. However, in-depth analyses of the model results were limited to the 5 year beach and inlet maintenance cycle. In all model runs, renourishment at Year 5 was neglected.

**TABLE 12-2**

**RANDOM SEQUENCES OF ANNUAL WAVES USED IN FUTURE CONDITIONS SIMULATIONS**

| Year of Project | Years from Wave Record Used in Random Wave Sequence in Run # ... | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Life | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| 1 | 2007 | 2009 | 2008 | 2000 | 2002 | 2004 | 2005 | 2002 | 2003 | 2003 | 2000 |
| 2 | 2008 | 2009 | 2008 | 2001 | 2004 | 2009 | 2001 | 2006 | 2005 | 2001 | 2001 |
| 3 | 2001 | 2004 | 2006 | 2007 | 2004 | 2003 | 2001 | 2004 | 2001 | 2007 | 2002 |
| 4 | 2008 | 2007 | 2007 | 2006 | 2006 | 2005 | 2002 | 2003 | 2000 | 2003 | 2003 |
| 5 | 2006 | 2001 | 2007 | 2003 | 2006 | 2002 | 2008 | 2007 | 2005 | 2005 | 2004 |
| 6 | 2001 | 2004 | 2004 | 2009 | 2007 | 2007 | 2002 | 2005 | 2007 | 2001 | 2005 |
| 7 | 2003 | 2008 | 2006 | 2000 | 2002 | 2002 | 2007 | 2005 | 2008 | 2005 | 2006 |
| 8 | 2005 | 2007 | 2002 | 2004 | 2006 | 2005 | 2002 | 2008 | 2001 | 2002 | 2007 |
| 9 | 2009 | 2009 | 2006 | 2003 | 2006 | 2006 | 2008 | 2003 | 2005 | 2006 | 2008 |
| 10 | 2009 | 2006 | 2000 | 2007 | 2001 | 2008 | 2003 | 2007 | 2004 | 2006 | 2009 |

### 12.5.1 Alternative 2

Projected shoreline positions under the Abandon/Retreat scenario appear in Figures 12-6 and 12-7. If the sandbags are removed, and beach maintenance is discontinued, a number of beachfront homes could be lost to erosion or severely damaged over the next 5 years. Properties at risk include all oceanfront parcels between 10 Comber Road and 9 Inlet Hook Road. Under a worst-case scenario, the pavement at the south end of Inlet Hook Road could also be at risk. The average, projected retreat along Inlet Hook Road (profiles 90+00 to 95+00) will range from 132 to 211 feet over 5 years.

Between profiles 60+00 and 75+00 (Surf Court), the GENESIS model predicts a stable shoreline. However, given past retreat rates (Table 6-1), 125 feet of shoreline retreat could occur on this reach over the next 5 years. Since the upland buildings along this area are located further landward than those further north, the erosion threat is not as critical.

Overall, the GENESIS model confirms that properties north of Surf Court will be subject to severe erosion over the next 5 years. Given the value of the homes being threatened, pressure to keep the sandbags in place and continue maintaining the beach is likely.

### 12.5.2 Alternatives 3 and 4

Projected shoreline positions under Alternative 3 appear in Figures 12-7 and 12-8. The GENESIS runs for Alternative 3 did not consider the effects of inlet modification. Although the ebb shoal would probably move if Alternative 3 were constructed (see Figures 11-49 and 11-50), these changes would not occur immediately. Preliminary simulations examined the sensitivity of the GENESIS and SWAN models to dredging in Rich Inlet. Specifically, the 2006 bathymetry


YEAR 0 AND YEAR 5 CONDITIONS GIVEN
ALTERNATIVE 2
ABANDON / RETREAT
COASTAL PLANNING & ENGINEERING, INC.
FIGURE 12-6A
LEGEND:
Δ 90+00 ORIGIN OF SURVEY PROFILES
NOTES:
1. COORDINATES ARE BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM IN FEET NAD 1983.
2. DATE OF AERIAL PHOTOGRAPH: APRIL 2007
NIXON CHANNEL
RICH INLET
ATLANTIC OCEAN
2007 MEAN HIGH WATER LINE EL = 1.70' NAVD
YEAR 5 GENESIS SHORELINE (AVERAGE, MOST LANDWARD, & MOST SEAWARD)
GRAPHIC SCALE IN FT
NORTH BEACH RD
MATCHLINE


MATCHLINE
YEAR 0 AND YEAR 5 CONDITIONS GIVEN
ALTERNATIVE 2
ABANDON / RETREAT
COASTAL PLANNING & ENGINEERING, INC.
FIGURE 12-6B
NORTH BEACH RD
SURF CT
ATLANTIC OCEAN
YEAR 5 GENESIS SHORELINE
(AVERAGE, MOST LANDWARD, & MOST SEAWARD)
2007 MEAN HIGH WATER
LINE EL = 1.70' NAVD
LEGEND:
△ 90+00 ORIGIN OF SURVEY PROFILES
NOTES:
1. COORDINATES ARE BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM IN FEET NAD 1983.
2. DATE OF AERIAL PHOTOGRAPH: APRIL 2007

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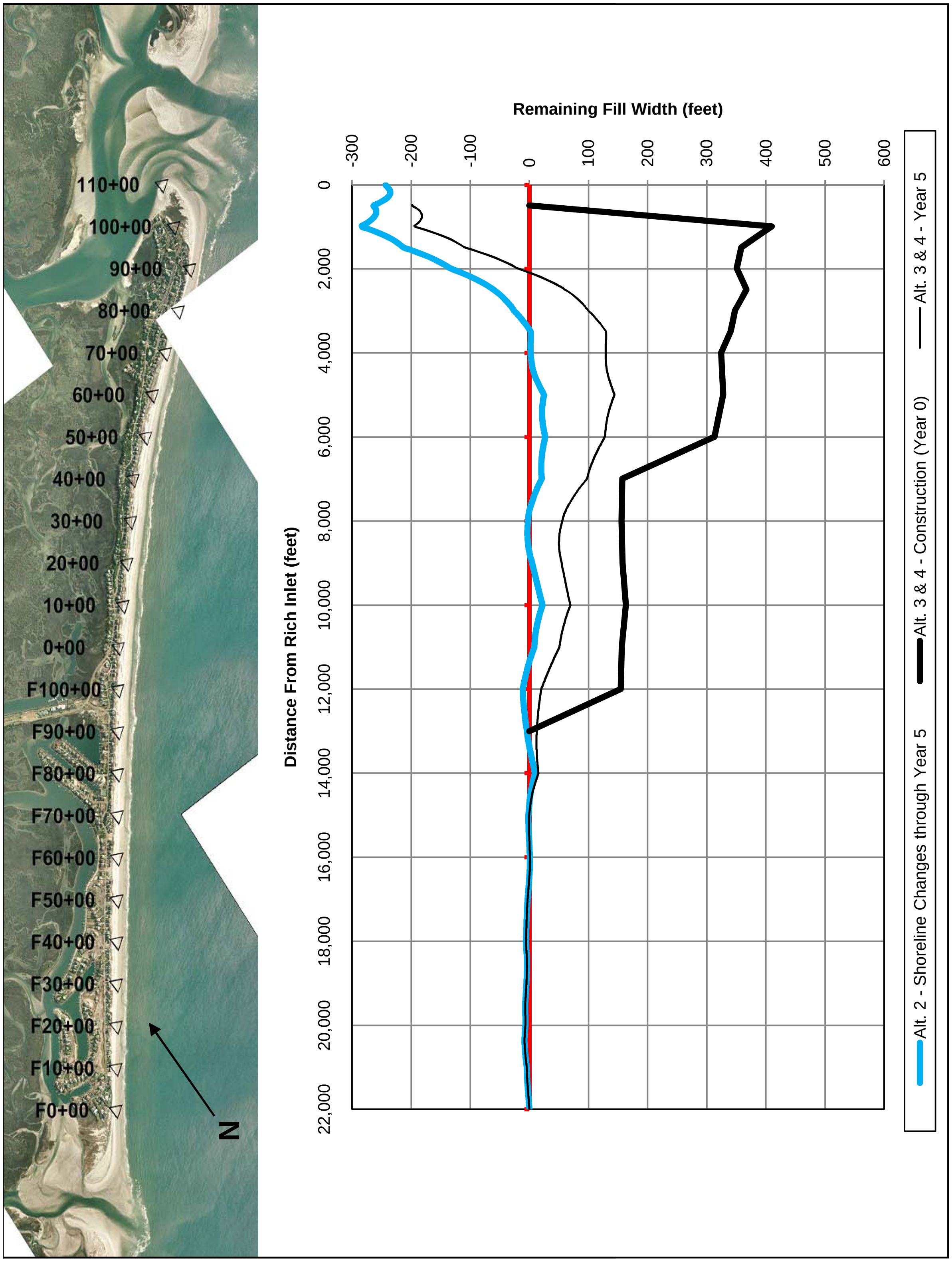


**FIGURE 12-7: Performance of Alternatives 2, 3, and 4 Based on the GENESIS Model.**


YEAR 0 AND YEAR 5 CONDITIONS GIVEN
ALTERNATIVE 3
RICH INLET MGMT. & BEACH FILL
COASTAL PLANNING & ENGINEERING, INC.
FIGURE 12-8A
RICH INLET
NIXON CHANNEL
ATLANTIC OCEAN
2007 MEAN HIGH WATER
LINE EL = 1.70' NAVD
GRAPHIC SCALE IN FT
YEAR 5 GENESIS SHORELINE
(AVERAGE, MOST LANDWARD,
& MOST SEAWARD)
YEAR 0 (CONSTRUCTION)
SHORELINE
NORTH BEACH RD
OYSTER CATCHER RD
LEGEND:
ORIGIN OF SURVEY PROFILES
NOTES:
1. COORDINATES ARE BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM IN FEET NAD 1983.
2. DATE OF AERIAL PHOTOGRAPH: APRIL 2007
MATCHLINE

YEAR 0 AND YEAR 5 CONDITIONS GIVEN
ALTERNATIVE 3
RICH INLET MGMT. & BEACH FILL
COASTAL PLANNING & ENGINEERING, INC.
FIGURE 12-88
MATCHLINE
YEAR 0 (CONSTRUCTION) SHORELINE
YEAR 5 GENESIS SHORELINE
(AVERAGE, MOST LANDWARD,
& MOST SEAWARD)
2007 MEAN HIGH WATER
LINE EL = 1.70' NAVD
ATLANTIC
OCEAN
NORTH BEACH RD
SURF CT
LEGEND:
△ 90+00 ORIGIN OF SURVEY PROFILES
NOTES:
1. COORDINATES ARE BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM IN FEET NAD 1983.
2. DATE OF AERIAL PHOTOGRAPH: APRIL 2007

(Figure 11-14) was replaced with the post-construction bathymetry under Alternatives 3 and 5A (see Figures 7 and 37 of Appendix E). Using the SWAN model and the 3 different bathymetries, refraction coefficients and wave directions were computed along the -24 foot NAVD contour. Although dredging altered the wave patterns within the inlet, it did not substantially change the refraction coefficients and wave directions along the GENESIS model domain. Had the wave transformation estimates for the GENESIS model been based on the bathymetries at Years 2 or 5, inlet dredging would have altered the refraction coefficients. However, the GENESIS model would no longer be independent from the Delft3D-FLOW model. For these reasons, all GENESIS runs in this section utilized the same refraction coefficients and nearshore wave angles.

Given Alternative 3, the GENESIS predicts that north of profile 90+00 (Inlet Hook Road), erosion past the pre-construction shoreline will occur by Year 5 (Figure 12-8). Along Inlet Hook Road, the Year 5 shoreline will coincide with the existing sandbags. The projected erosion patterns under Alternative 3 are similar in both the GENESIS and Delft3D-FLOW models (see Figures 12-7 and 11-45). Overall, both models suggest that while Alternative 3 will reduce the erosion threat along the north end of the island, it does not completely mitigate for the erosion along the most critically eroded area (profiles 90+00 to 95+00).

Alternatives 3 and 4 shared the same beach fill layout. Since inlet dredging was neglected in the GENESIS model, all GENESIS results for Alternative 3 were applicable to Alternative 4.

### 12.5.3 Alternatives 5A

Projected shoreline positions under Alternative 5A appear in Figures 12-9 and 12-10. As noted above, inlet dredging was neglected in the GENESIS model. The groin length considered in the GENESIS model was 700 feet relative to the pre-construction (April 2007) shoreline.

Given the construction of a terminal groin with beach fill, the GENESIS model predicts that there will be no erosion into the pre-construction shoreline between Years 0 and 5. This finding is generally consistent with the Delft3D results in Figure 11-52. The primary differences between the two models are the distribution of the remaining fill at Year 5 and the shape of the fillet. North of Surf Court (profile 70+00), the GENESIS model predicts a relatively uniform distribution of remaining fill at Year 5. In contrast, the Delft3D-FLOW model predicts erosion back to the pre-construction profile at profile 90+00 (Inlet Hook Road) (see Figure 11-52). The GENESIS model predicts a convex fillet shape near the groin (see Figure 12-9), unlike the Delft3D-FLOW model (see Figure 11-54). There are two possible reasons for the unusual fillet shape:

LEGEND:

△ 90+00 ORIGIN OF SURVEY PROFILES

NOTES:

1. COORDINATES ARE BASED ON NORTH CAROLINA STATE PLANE COORDINATE SYSTEM IN FEET NAD 1983.
2. DATE OF AERIAL PHOTOGRAPH: APRIL 2007


YEAR 0 AND YEAR 5 CONDITIONS GIVEN
ALTERNATIVE 5A
TERMINAL GROIN WITH BEACH FILL

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
www.CoastalPlanning.net
PH. (561) 391-8102
FAX (561) 391-9116

FIGURE 12-9A


YEAR 0 AND YEAR 5 CONDITIONS GIVEN
ALTERNATIVE 5A
TERMINAL GROIN WITH BEACH FILL

COASTAL PLANNING & ENGINEERING, INC.
2481 N.W. BOCA RATON BOULEVARD
BOCA RATON, FLORIDA 33431
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FAX (561) 391-9116
www.CoastalPlanning.net

FIGURE 12-9B

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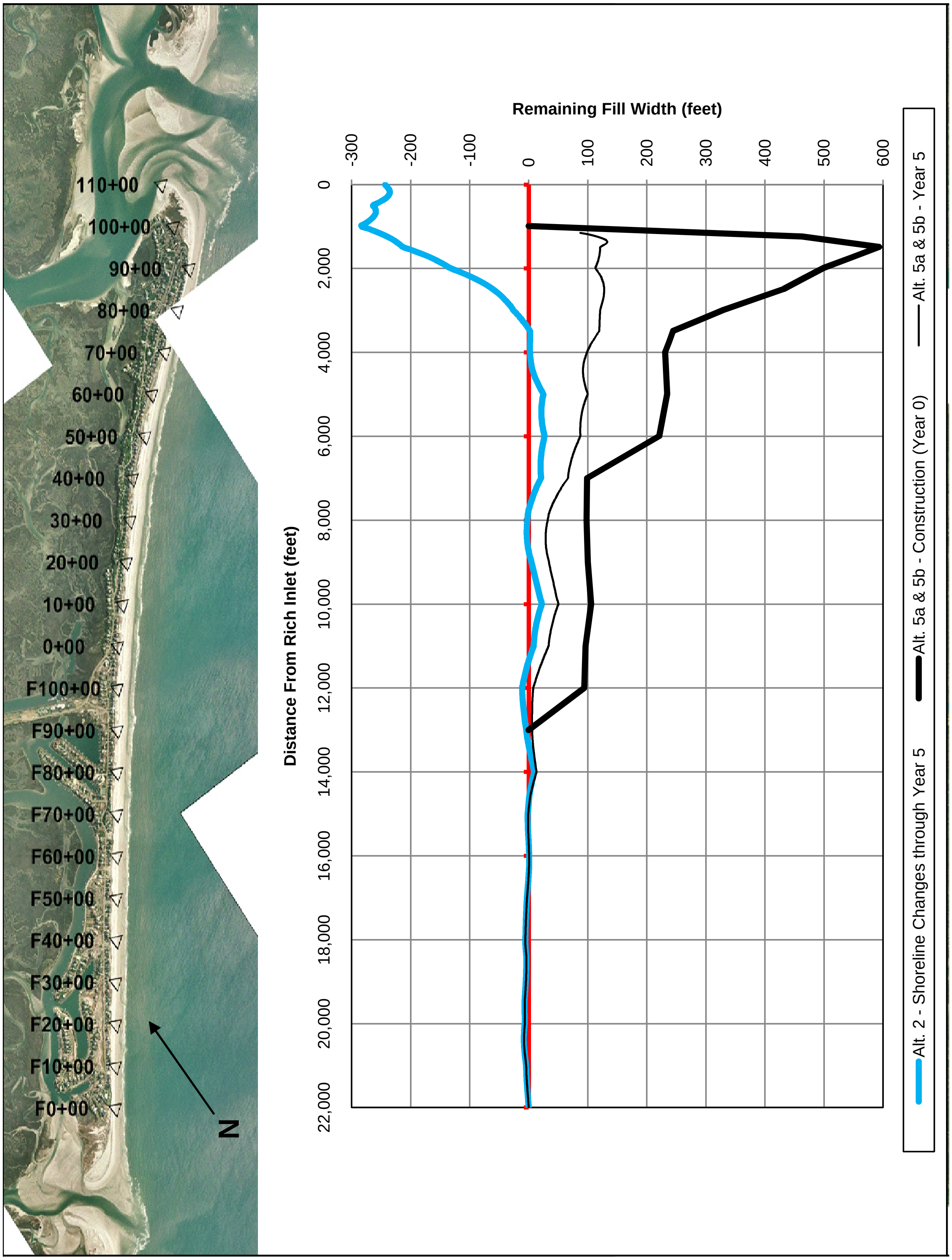


FIGURE 12-10: Performance of Alternatives 2, 5a, and 5b Based on the GENESIS Model.

1. The wave refractions coefficients for the GENESIS model are specified at the depth of closure (-24 feet NAVD). Based on the Delft3D-FLOW results in Sub-Appendix D, Figure 46, Alternative 5A has very little impact on the position of the -24 foot NAVD contour. Thus, the nearshore processes that would generate a typical concave fillet may not be fully resolved in the GENESIS model.

2. The natural shoreline shape and the offshore bathymetry might be influencing the shape of the groin fillet. This effect occurs at New Pass, Sarasota County, FL (see Figure 12-10A). Similar to Rich Inlet, the natural shoreline shape is convex. In addition, at both Rich Inlet and New Pass, the bulk of the ebb shoal and the terminal groin are located on opposite sides of the inlet.

Given the performance of terminal groins closer to the project area, the convex fillet shape predicted by the Delft3D-FLOW model (Figure 11-54) is more likely.

In spite of the differences between the Delft3D and GENESIS models, both show models that by including a terminal groin, Alternative 5A:

- Can completely address erosion along the fill area over 5 years using less material than Alternative 3.

- Leaves more material within the fill area at Year 5 than Alternative 3, both in terms of the absolute quantity (c.y.) and the percentage of fill.

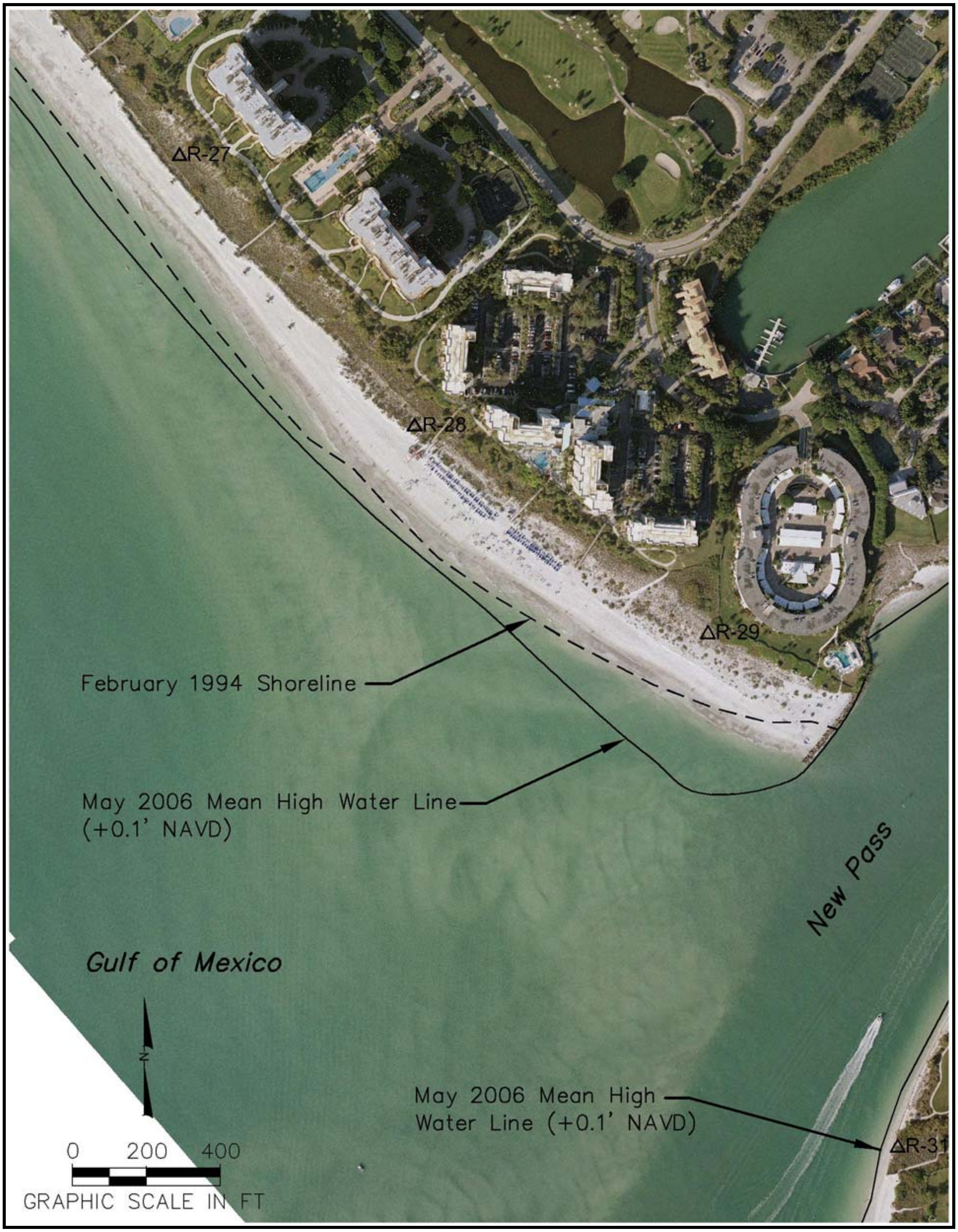


**FIGURE 12-10A: New Pass Terminal Groin with December 30, 2009 Aerial, Sarasota County, FL.**

### 12.5.5 Summary

While 5-year predictions of the GENESIS and Delft3D-FLOW models differ in their details, they both suggest similar trends in the performance of Alternatives 2, 3, and 5A. The general findings of one model generally support the other. Recommendations based on the model results and the historical erosion analysis in Sections 6 and 7 appear in the final conclusions and recommendations of this report.

## 13.0 COST ESTIMATES

The following tables provide opinions on costs for Alternatives 3, 4, 5A, 5B, and 5C.

**Table 13-1**
**Cost Estimate – Alternative 3**
**Rich Inlet Management with Beach Fill**

| **First Cost** | | | | |
|---|---|---|---|---|
| Item | Unit | Quantity | Unit Cost | Cost |
| Beach fill from Green and Inlet Channel | | | | |
| Mobilization and Demobilization | LS | 1 | $2,760,000 | $2,760,000 |
| Dredging (Beach Fill) | CY | 1,239,200 | $6.64 | $8,223,000 |
| Sub-Total (Beach Fill) | | | | $10,983,000 |
| Construct Dike – Upland Disposal of Clay | | | | |
| Additional Mob & Demob – Pipe | LS | 1 | $230,000 | $230,000 |
| Modify Upland Disposal Site | Job | 1 | $288,000 | $288,000 |
| Dredging – Dike & Upland Disposal | CY | 534,100 | $6.64 | $3,544,000 |
| Sub-Total Dike & Upland Disposal | | | | $4,062,000 |
| Dune Vegetation | LF | 1,250 | $2.30 | $3,000 |
| Total Construction Cost | | | | $15,048,000 |
| Engineering & Design (P&S) | | | | $150,000 |
| Construction Oversight | | | | $120,000 |
| **Total First Cost** | | | | **$15,318,000** |
| **Periodic Channel Maintenance and Beach Nourishment (Every 5 years)** | | | | |
| Mobilization and Demobilization | LS | 1 | $2,760,000 | $2,760,000 |
| Dredging Entrance Channel & Beach Fill | CY | 716,000 | $6.64 | $4,751,000 |
| Sub-Total | | | | $7,511,000 |
| Engineering & Design (P&S) | | | | $100,000 |
| Construction Oversight | | | | $120,000 |
| **Total Periodic Dredging Cost** | | | | **$7,731,000** |

**Table 13-2**
**Cost Estimate – Alternative 4**
**Beach Nourishment without Inlet Management**

| **First Cost** | | | | |
|---|---|---|---|---|
| Item | Unit | Quantity | Unit Cost | Cost |
| Hopper Dredge – Offshore Borrow Areas | | | | |
| Mobilization and Demobilization | LS | 1 | $2,464,000 | $2,464,000 |
| Dredging (Beach Fill) | CY | 529,300 | $12.33 | $6,524,000 |
| Sub-Total (Offshore Borrow Areas) | | | | $8,988,000 |
| 18-inch Pipeline Dredge – Nixon Channel | | | | |
| Mobilization and Demobilization | LS | 1 | $536,000 | $536,000 |
| Dredging – Nixon Channel | CY | 400,000 | $6.06 | $2,424,000 |
| Sub-Total Nixon Channel | | | | $2,960,000 |
| Dune Vegetation | LF | 1,250 | $2.30 | $3,000 |
| Total Construction Cost | | | | $11,951,000 |
| Engineering & Design (P&S) | | | | $150,000 |
| Construction Oversight | | | | $170,000 |
| **Total First Cost** | | | | **$12,271,000** |
| **Periodic Channel Maintenance and Beach Nourishment (Every 3 years)** | | | | |
| Hopper Dredge – Offshore Borrow Areas | | | | |
| Mobilization and Demobilization | LS | 1 | $2,464,000 | $2,464,000 |
| Dredging (Beach Fill) | CY | 270,000 | $12.33 | $3,328,000 |
| Sub-Total (Offshore Borrow Areas) | | | | $5,792,000 |
| 18-inch Pipeline Dredge – Nixon Channel | | | | |
| Mobilization and Demobilization | LS | 1 | $536,000 | $536,000 |
| Dredging – Nixon Channel | CY | 400,000 | $6.06 | $2,424,000 |
| Sub-Total Nixon Channel | | | | $2,960,000 |
| Total Construction Cost | | | | $8,752,000 |
| Engineering & Design (P&S) | | | | $100,000 |
| Construction Oversight | | | | $170,000 |
| **Total 4-year Nourishment Cost** | | | | **$9,022,000** |

**Table 13-3**
**Cost Estimate – Alternative 5A**
**Terminal Groin with Beach Fill from Maintenance of the Nixon Channel Navigation Channel and Connector Channel**

| **First Cost** | | | | |
|---|---|---|---|---|
| Item | Unit | Quantity | Unit Cost | Cost |
| **18-inch Pipeline – Nixon Channel & Beach Fill** | | | | |
| Mobilization and Demobilization | LS | 1 | $1,910,000 | $1,910,000 |
| Dredging (Channel & Beach Fill) | CY | 994,900 | $6.98 | $6,945,000 |
| Dune Vegetation | LF | 1,250 | $2.30 | $3,000 |
| Sub-Total (Channel & Beach Fill) | | | | $8,858,000 |
| Engineering & Design (P&S) | | | | $100,000 |
| Construction Oversight | | | | $120,000 |
| **Total First Cost Channel & Beach Fill** | | | | **$9,078,000** |
| | | | | |
| **Terminal Groin** | | | | |
| Groin Construction | LF | 1,600 | $1,800 | $2,880,000 |
| Navigation Aid (3-pile dolphin & light) | | | | $15,000 |
| Sub-Total Terminal Groin | | | | $2,895,000 |
| Engineering & Design (P&S) | | | | $200,000 |
| Construction Oversight | | | | $220,000 |
| **Total First Cost Terminal Groin** | | | | **$3,315,000** |
| | | | | |
| **Total First Cost Alternative 5A** | | | | **$12,393,000** |
| | | | | |
| **Periodic Channel Maintenance & Beach Nourishment (Every 5 years)** | | | | |
| Mobilization and Demobilization | LS | 1 | $1,909,000 | $1,909,000 |
| Dredging | CY | 472,000 | $6.98 | $3,295,000 |
| Total Periodic Dredging Cost | | | | $5,204,000 |
| Engineering & Design (P&S) | | | | $100,000 |
| Construction Oversight | | | | $120,000 |
| **Total Periodic Cost (every 5 years)** | | | | **$5,424,000** |

**Table 13-4**
**Cost Estimate – Alternative 5B**
**Terminal Groin with Beach Fill From Other Sources**

| **First Cost** | | | | |
|---|---|---|---|---|
| Item | Unit | Quantity | Unit Cost | Cost |
| | | | | |
| | | | | |
| 18-inch Pipeline Dredge – Nixon Channel | | | | |
| Mobilization and Demobilization | LS | 1 | $536,000 | $536,000 |
| Dredging – Nixon Channel | CY | 289,800 | $6.06 | $1,756,000 |
| Sub-Total Nixon Channel | | | | $2,292,000 |
| Dune Vegetation | LF | 1,250 | $2.30 | $3,000 |
| Sub-Total Beach Fill & Dune | | | | $2,295,000 |
| Engineering & Design (P&S) | | | | $150,000 |
| Construction Oversight | | | | $170,000 |
| **Total Construction Beach Fill & Dune** | | | | **$2,615,000** |
| | | | | |
| **Terminal Groin** | | | | |
| Groin Construction | LF | 1,600 | $1,800 | $3,872,000 |
| Navigation Aid (3-pile dolphin & light) | | | | $15,000 |
| Sub-Total Terminal Groin | | | | $2,895,000 |
| Engineering & Design (P&S) | | | | $200,000 |
| Construction Oversight | | | | $220,000 |
| **Total First Cost Terminal Groin** | | | | **$3,315,000** |
| | | | | |
| **Total First Cost Alternative 5B** | | | | **$5,930,000** |
| | | | | |
| **Periodic Channel Maintenance & Beach Nourishment (Every 5 years)** | | | | |
| Mobilization and Demobilization | LS | 1 | $536,000 | $536,000 |
| Dredging | CY | 175,800 | $6.98 | $1,065,000 |
| Total Periodic Dredging Cost | | | | $1,601,000 |
| Engineering & Design (P&S) | | | | $100,000 |
| Construction Oversight | | | | $170,000 |
| **Total Periodic Cost (every 5 years)** | | | | **$1,821,000** |

## 14.0 CONCLUSIONS AND RECOMMENDATIONS

The north end of Figure Eight Island has suffered from severe erosion since 1998. This erosion occurs in two locations: the oceanfront beach and the northern-facing shoreline along Nixon Channel. On the oceanfront beach, the high erosion rates are due to the movement of the Rich Inlet entrance channel away from Figure Eight Island, taking the ebb shoal and the protection that it offers against erosion with it. Along Nixon Channel, the high erosion rates are due to the migration of the deep section of the channel towards the developed properties facing it. This study offers 2 viable alternatives to address the high erosion rates:

<u>Alternative 3: Rich Inlet Management and Beach Fill:</u> This alternative would construct the optimum entrance channel that would favor the stability or build-up of the oceanfront beach on the north end of Figure Eight Island, based on the analysis of Cleary and Jackson (2004). It would also construct a short connecting cut to the seaward terminus of Green Channel and a long connecting cut into Nixon Channel to relocate the deep section of Nixon Channel away from the heavily eroded properties on the north end of Beach Road.

- Volume: 1,773,300 c.y. + 150,400 c.y. overdepth (1,923,700 c.y. total).

- Cut depth: -19 feet NAVD + 1 foot overdepth.

- Dredged Material Disposal Areas:
  - Closure dike across the deep section of the existing entrance channel, 28%.
  - Nixon Channel beach fill area (538-552 Beach Road N), 4%.
  - Oceanfront beach fill area (8 Beach Road S to Rich Inlet), 68%.

- Advantages:
  - Can be constructed under present state statutes.
  - Permitting agencies are familiar with this approach.
  - Similar projects of this sort have been constructed at Bogue Inlet and Shallotte Inlet.

- Disadvantages:
  - The renourishment interval may need to be shorter than 5 years on the north end of the island.
  - There is also the risk that the channel and/or ebb shoal might not behave in the manner that has been anticipated based on the historic trends (i.e.: Cleary and Jackson, 2004) and model results. If a major hurricane such as Fran (1996) alters the inlet unexpectedly, the erosion rates on the north end of the island could revert to the present levels.

<u>Alternative 5B, Terminal Groin with Beach Fill from Other Sources:</u> This alternative would construct a terminal groin on the north end of Figure Eight Island to slow down the transport of eroded material from the north end of the island into Rich Inlet and retain some sediment in a permanent accretion fillet. An adjoining fill area would be placed to pre-fill the groin and nourish the beach 4,000 feet south of the terminal groin. Based on the Delft3D model results, an initial beach nourishment would not be required south of station 60+00 to Bridge Road but could require future periodic nourishment. The beach fill material would be derived from maintenance of the existing permitted navigation channel in Nixon Channel which could be supplemented with material removed from the northern upland disposal sites located adjacent to the AIWW. Alternative 5B also

includes a beach fill along the south side of Nixon Channel with the material for this fill also obtained from maintenance of the existing navigation channel.

- Terminal groin length = 700 feet from the April 2007 shoreline, 1,600 feet total.

- Terminal groin footprint (bottom surface area) = 1.1 acres.

- Groin crest elevation:
    - Landward segment (700 feet): +4 feet NAVD.
    - Main segment (800 feet): +6 feet NAVD.
    - Sloping segment near construction shoreline (37 feet): +3.5 to +6 feet NAVD.
    - Most seaward segment (163 feet): +3.5 feet NAVD.

- Groin material: Sheet Pile (concrete or steel) and Granite quarry stone. Armor stone ranging from 3.8 tons on landward end to 12.5 tons on seaward end.

    - Dredge Volume = 289,800 cubic yards

    - Dredge Cut Depth = -11.43 + 1 foot overdepth.

    - Dredged Material Disposal Areas:
        - Nixon Channel beach fill area (538-552 Beach Road N), 13%.
        - Oceanfront beach fill area (Intersection of Beachbay Lane and Bridge Road to Rich Inlet), 87%.

    - Advantages:
        - The structure can directly slow the high erosion rates on the north end of the island by partially blocking sand transport into Rich Inlet.
        - The existing permit area in Nixon Channel would serve as the sole source of beach fill material, therefore, no new borrow sources would be needed.
        - The dredging requirement is 28% of the volume for Alternative 3.
        - The project footprint is smaller, resulting in less physical impact in terms of affected acreage.
        - The likelihood of success is greater than Alternative 3, since it is less dependent on processes in the inlet and the ebb shoal, which are difficult to control.

    - Disadvantage:
        - Periodic beach nourishment would be required approximately every 4 years compared to every 5 years for Alternative 3.

Given the erosional trends, sediment transport patterns, project performance estimates, and present renourishment schedule for the north end of Figure Eight Island, Alternative 5C would be the better alternative.

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**Sub-Appendix A**

**Rich Inlet Update**
**by**
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**Sub-Appendix B**

**Delft3D Model Results**